JULY 1977

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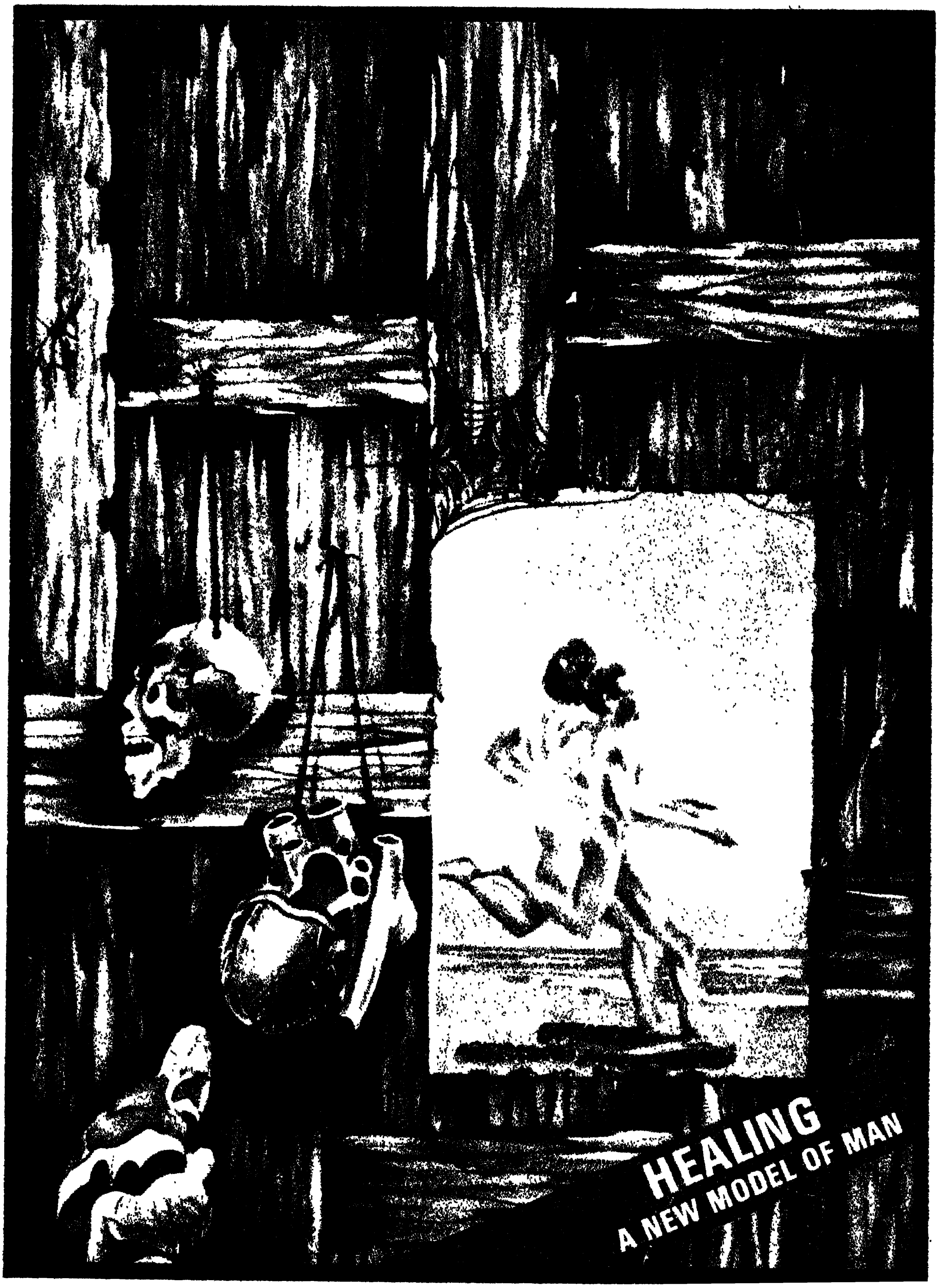
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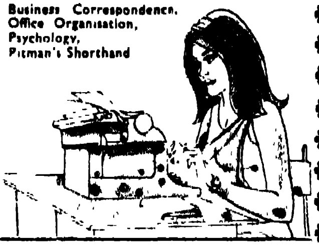

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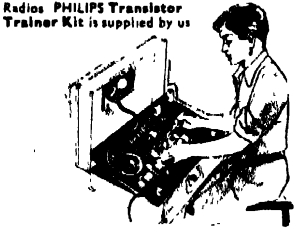

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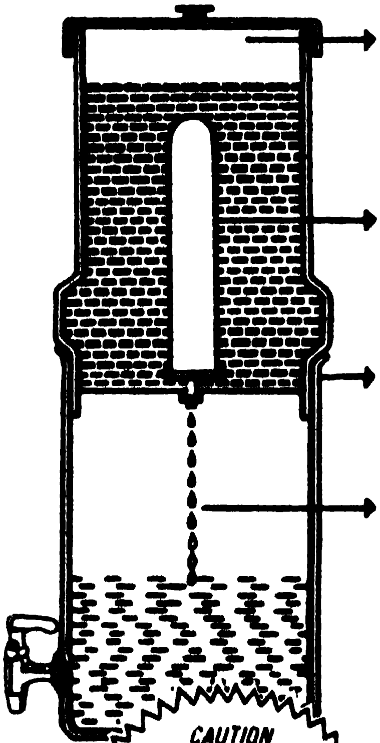

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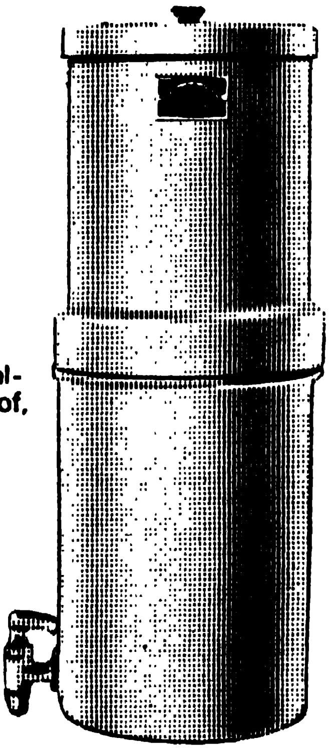

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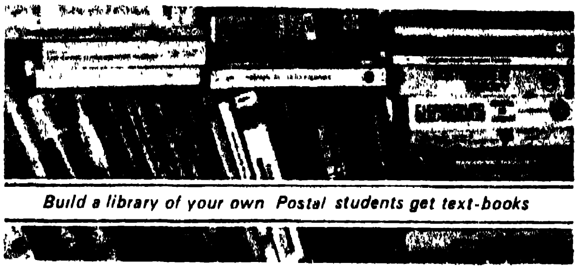

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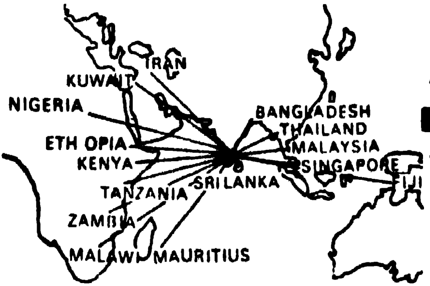

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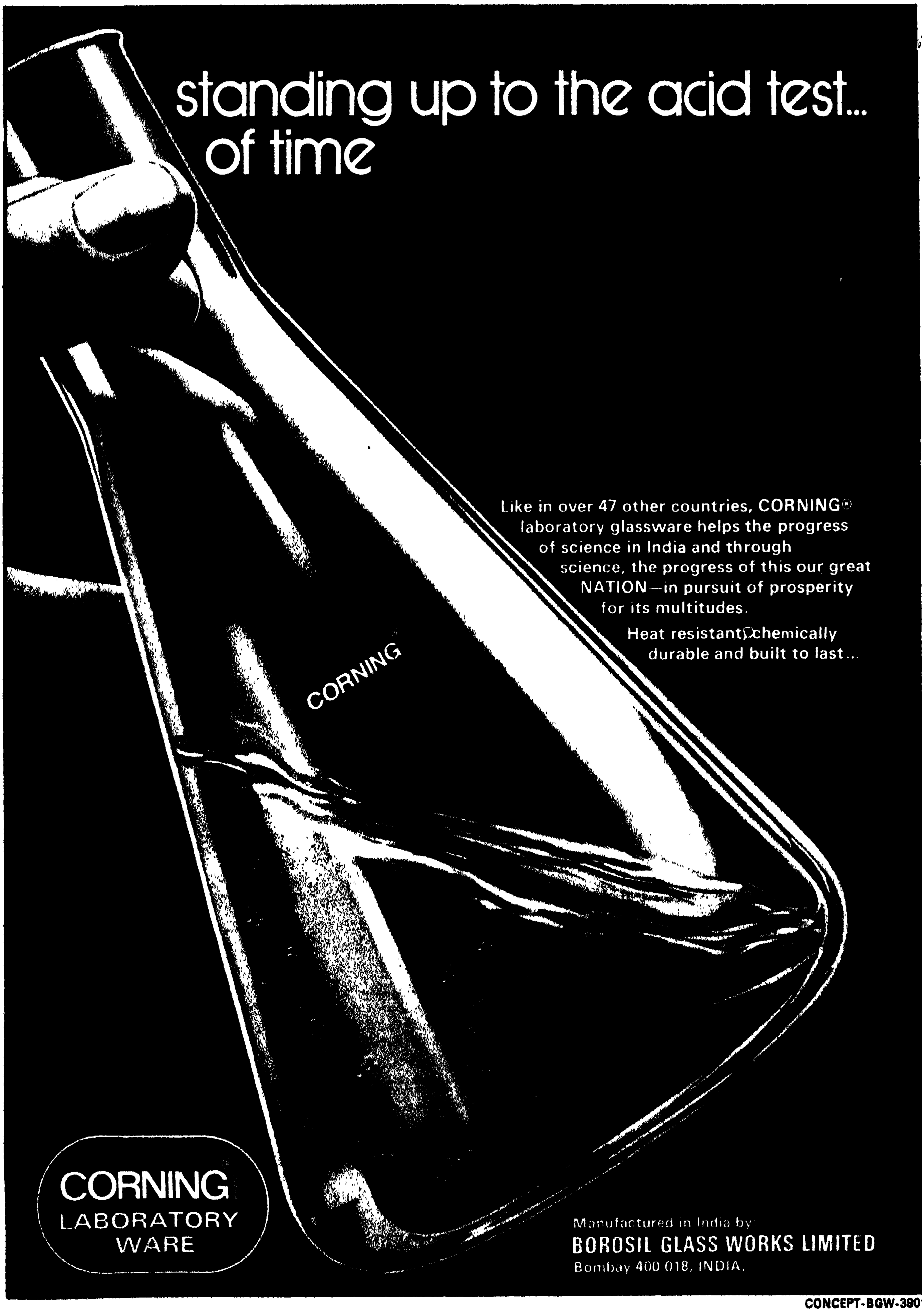

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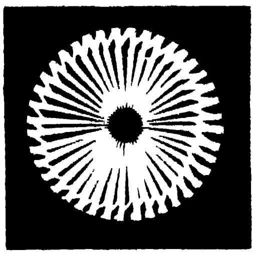
K. L. Chopra



The tremendous advances made by the science and technology of thin solid films have led to the creation of many new scientific disciplines. Here's an outline of some of its aspects

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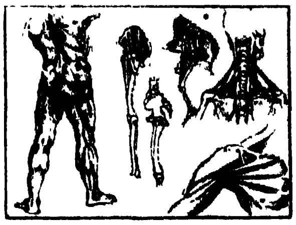

The physician's model of disease has no room for the social and psychological dimensions of illness. Are we ready to change the model?

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Because aerodynamics comes in, " failures " have learned to become world champions

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Wash-n-wear finishing

Textile finishing is not a gimmick ("Cotton fabrics and the finishing gimmicks", April 1977). In fact, it is an exact science. Koratrom Co of the USA and Tootal Broadhurst and Lee of England have laid down fabric specifications, depending on end-uses, and they specifically insist that in no case a customer should be cheated. Only when strength characteristics mentioned in their manual are maintained in the fabrics do they permit their resin finish labelling.

Wash and wear is an important improvement in the overall concept of resin finishing. Durable-press (DP) is a step forward, with higher crease recovery angles and no need to iron the DP garments after washing

DP fabrics have the highest amount of resin added on. As the resin add-on is increased, wash and wear properties improve. However, simultaneously, degradation (or loss in strength retention) sets in. The more the resin added, such as for DP level, the higher will be the strength loss — to the tune of 30 to 55 per cent.

The level of resin finishing done depends upon the initial quality of the fabric. Only fabrics with highest strengths are given a high resin add-on, or, in other words, only those fabrics that can stand such high resin add-on and still maintain performance characteristics are given DP treatments. Weaker fabrics get shrink-resistant or anticrease finishes. Still weaker fabrics are never given any treatment.

The success of DP garments depends on. (i) finishing mills, (ii) garment manufacturers, and (iii) the care exercised during home washings. In India, the DP concept has failed. All the finishes are more or less "wash-n-wear" or with still lower levels of anticrease. Anyway, they are better than untreated fabrics so far as ironing is concerned, they need only mild ironing or a touch of ironing for a sharp wear after washing.

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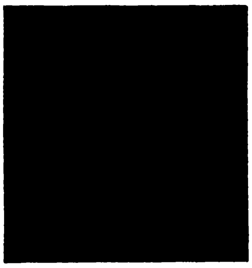
Black holes?



First detailed colour photograph of a black hole. Note features at upper left and centre, in good agreement with current theoretical predictions.

The "first detailed colour photograph of a black hole (May 1977, p. 17) was just that — a black hole! Was there a mistake?

JAYANTH KURIYAN
Hyderabad

No mistake. *Mercury* had printed it as a joke. Since black holes trap even light, they must remain invisible!—Ed.

Bathroom singing

Mr. Chander Shekhar is right when he says that males sing more frequently in the bathroom than females ("Letters", May 1977). But why do they sing at all? That one feels more relaxed when water cools the nerves is not true, because then it should be the same in both the sexes. The reason is more psychological and physiological. There is an echo of our voice in the closed environment of the bathroom which pleases our ears, and we sing more and more. It is also known that female voices have a higher frequency compared to males'; they do not produce such a good echo as male voices.

UMA KANT SHARMA
P.O. Kasimpur, Aligarh-202 127

One reason why men sing more frequently than females may be that men always pour water over their heads while bathing, whereas women usually do not wet their heads. Thus, the relaxing effect is more pronounced in males.

RAJIV SHARMA
E1/15, Model Town, Delhi-110 009

Cockroaches and homeopathy

This has reference to the news item "Cockroaches and asthma" (May 1977, p. 9). The homeopathic ***Materia medica*** is based on symptoms produced in healthy males and females by administering drugs in material doses. The same drug in dilutions ranging from 10^{-3} to 10^{-200} or more is given for a disease which has symptoms similar to that produced by the drug It is considered that the drug thus diluted provokes a reaction in the body which destroys the disease-producing noxious agent This is similar to the preventive therapy in modern medicine Diseases like diphtheria, whooping cough, tetanus, typhoid, cholera, polio, smallpox, etc are eradicated on this principle.

There are some diseases which are cured or relieved by homeopathic drugs which have been discovered accidentally. ***Blatta orientalis***, or the cockroach, is one such. It has been used for many decades as a homeopathic drug to cure or relieve asthma. According to the homeopathic principle, the cockroach should cause asthma, and this is now proved to be true.

M. S. KIRLOSKAR
Sadhankeri, Dharwar-580 008

AWARDS & APPOINTMENTS

Swaminathan elected to US academy

Dr. M. S. Swaminathan, Director-General, Indian Council of Agricultural Research (ICAR), has been elected Foreign Associate of the National Academy of

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ate of the US iences. The other igaswami (1973), idia Institute of w Delhi, and Dr. o of the Physical Research Laboratory, Ahmedabad. Dr. Swaminathan has been chosen for his outstanding contributions to applied genetics and biology.

Nehru Fellowship

Dr. S. Ramaseshan, head of the materials division section of the National Aeronautical Laboratory, Bangalore, has been awarded the Nehru Fellowship. He will study "the life and work of Sir C. V. Raman". Dr. Ramaseshan's main fields of work are optics, anomalous scattering of X-rays and neutrons, and low-temperature crystallography. He is a former student of the late Sir C. V. Raman.

Industrial design

The National Institute of Design, Ahmedabad, has won the first award of the International Council of Societies of Industrial Design, Eindhoven, Netherlands.

Dr. Joshi honoured

Dr. A. B. Joshi, Vice-chancellor of the Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, and former Director of the Indian Agricultural Research Institute, has been appointed a member of the International Board for Plant Genetic Resource (IBPGR), Rome, and of the Technical Advisory Committee (TAC) of the Consultative Group of International Agricultural Research, Rome.

Dr. B. C. Roy award

Dr. T. Manickam, an ENT specialist and president of the Karnataka Medical Council, has been given the Dr. B. C. Roy award in the category for "encouraging and development of specialities in different branches of medicine." Dr. Manickam had founded the Venkateshwara ENT Institute at the Victoria Hospital in Bangalore. He had also helped to set up modern ENT services in several district hospitals. The other winner, in the category for teaching, is Dr. G. S. Sainani, professor and head of the Department of Medicine, B. J. Medical College, Pune (see SCIENCE TODAY, May 1977, p. 61).

TV IN INDIA: EDUCATION OR ENTERTAINMENT?

It appears that television has come to stay in India. Now that it is soon going to be in the hands of a new policy-making body, an autonomous corporation, it is worthwhile to stimulate discussions at this stage to review past achievements and to visualise possible goals for the future. The arguments here deal with regular telecasts and exclude consideration of the SITE project which was a separate experiment, special in many ways.

The introduction of television in India was marked by the promise that it would play a significant role in national development, and this promise continues to be renewed from time to time. It is time to ask, if this promise has been fulfilled in any major way? Has television been effectively used as an instrument for education? Has adequate attention been paid to the areas which are important to us, for instance in:

- Providing significant assistance to school teaching;
- Providing forums for education outside traditional institutions, providing for life-long education;
- Enriching the learning environment of young children;
- Educating the underprivileged, especially in the rural areas, about their rights, and the various government schemes meant for their benefit, which often fail to reach them?

Though TV transmitters are located in urban centres, their range does cover large rural populations. They are, however, too poor to profit from it in the absence of community sets.

We should also ask if TV has made a serious effort to evaluate modern educational techniques being developed elsewhere that would be relevant to India? Has it encouraged, stimulated or sponsored the development of such techniques indigenously?

A specific example of a major development in this area is the British Open University which, using a 300-man production team in the BBC, has employed television to make post-school education inexpensive, widely accessible, available to the working adult and relevant to the realities of life.

The questions we have raised here relate to serious or 'hard' attempts in education. Any TV programme, say, an interview with an economist here or a political commentator there, can be claimed to be educational. News, or even an essentially frivolous word-game, can be presented in this light. We do not contest the argument that most TV programmes have some incidental educational value. But we would like to preclude attempts to confuse such programmes with hard educational programmes which have been professionally designed and evaluated for their educational effectiveness. That such educational programmes can attract and hold large audiences has been adequately established.

TV shapes its own audience

One of the arguments put forth by TV producers is that they have to give the viewers what they want; otherwise, they just turn off.

This is, in a sense, true. But the argument can easily be turned around, especially in our situation with TV in its early stages of expansion. What is telecast in the early years will determine the nature of the viewing population we gather and their expectation in the years to come. If we go in mainly for entertainment and provide an inadequate educational component, entertainment will almost certainly grow to be the dominant feature and TV will get out of hand. We are afraid that this trend has set in already, and if it continues, there will be no incentive for any one to increase school ownership and other community ownership of TV sets. TV will become essentially the entertainer of the upper middle class, despite all claims about its role in education. We are concerned with the fact that schools equipped with TV in India today constitute a negligible percentage of the total, and with the fact that the effort going into production of well-designed educational TV programmes is very limited. It is a pity that we have to depend on imported science programmes for quality and effectiveness, largely because of the scarcity of impressive Indian programmes.

At present, the body that produces educational programmes and telecasts them is not responsible for ensuring their effective utilisation. Individuals and individual systems of schools may or may not use them, and there is no clear minimum expectation to be fulfilled. Admittedly, TV receivers are very expensive for schools to purchase, but a good part of the expense is due to taxes which can surely be waived in some way or the other, for sets owned by schools or the community. There is a fear about maintenance of large numbers of receivers, though the Indian experience clearly indicates that the problem is managerial rather than technical. There is also some concern that expenditure on educational TV can be easily diverted to benefit the privileged urban viewers, who already have access to reasonably good education rather than the underprivileged going to the poorer schools or not going to school at all.

What is needed now is an unambiguous commitment to the objective of making TV play a major role in education. This can be ensured only by taking adequate steps at the time of setting up the autonomous corporation. This corporation should be given proper direction by its written constitution and mandate, to bring TV to bear on India's educational development. If we do not attempt this at this stage we will surely miss the bus.

In this last quarter of the 20th century, a nation like India faces many special problems. It also has opportunities that others did not have at a comparable state of development, educational TV being a good example. In the final analysis, it is the political will which is going to decide if planning for television takes the right direction.

B. M. UDGAONKAR
S. RAMANI

[illegible] towards a degree. [illegible] programmes are also watched by thousands of [illegible] have enrolled.

UMA tailors [illegible] target groups. To provide [illegible] material (including tests to be self-administered) to the non-enrolled people, UMA persuaded a local newspaper (readership 300,000) to carry a series of articles to accompany its courses. The first series telecast was on "Accounting" and it was shown to be highly popular on the basis of a readership survey. Nine per cent of the readers followed the articles, a record beaten only by the comic strips, sports news and the Ann Landers (personal questions) column.

S.R.

B. M. Udgaonkar is a professor at the Tata Institute of Fundamental Research, Bombay, and S. Ramani is a research scientist in the same Institute. Professor Udgaonkar is also a member of the University Grants Commission; Dr. Ramani is active in the field of Educational Technology.

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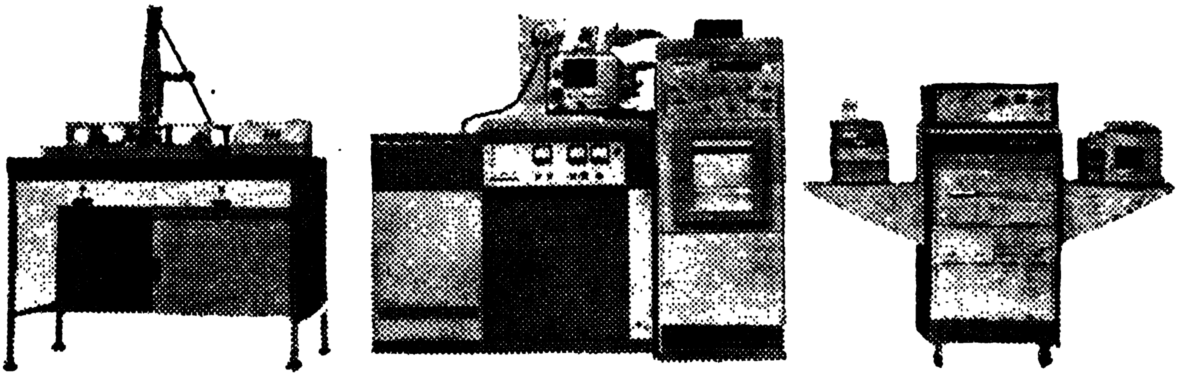

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BIG CITIES GOOD, SMALL CITIES BAD

When somebody inveighs against the glass and concrete jungles of today, which are commonly believed to affect the quality of life, there is something you can stop his mouth with it is the follow-up study of the famous Mid-town Manhattan Study of 1954. The follow-up suggests that contrary to accepted views, small towns and rural areas don't necessarily have an edge over big cities in providing a congenial environment for humans. Apparently, man is resilient enough to adapt himself to urban chaos after a generation or two.

Many were shocked by the findings of Leo Srole of Columbia University (USA) in the 1954 study that 23 per cent of New York's East-Side residents were in need of psychiatric treatment, but they later accepted it as true of most cities. In the follow-up study, Srole reports that the mental health of Manhattan residents has improved greatly, compared to small city and town dwellers. In the 1974 study, Manhattan subjects answered almost the same questions on symptoms they had answered 20 years ago. The answers from persons 40 to 60 years old were compared with those of respondents in the same age-range in 1954, the samples in both the studies are representative of both rich and poor persons in predominantly white areas.

During the two decades, persons with 'impaired' mental capacity in the 40 to 49 and 50 to 59 age-groups dropped from 16 to 8·4 per cent and 21·7 to 10·3 per cent, respectively. To explain this, Srole says that respondents in their fifties in the first survey were brought up by parents who grew up in the late 1800s, and their environmental, occupational and educational settings were quite different from those of the 1974 respondents.

Srole combined his study with data from other surveys and concludes, in a presentation at the American Psychiatric Association last May in Toronto, that persons who lived in rural areas and in cities of fewer than 50,000 population had higher symptom scores than people who lived in cities with larger populations.

WHY BABY LANGURS GET KILLED

Probably the most startling finding in recent years by those who study primates is that those we regard as our closest relatives, among all orders of mammals, are a blood-thirsty lot. About a dozen species, representing every group of primates, both in the New World and the Old World, are now known in which infants are killed whenever a male takes over a group; this is apart from cases of adults fighting each other to the death. Males attack infants when they come into possession of females accompanied by offspring sired by another male. Such killings have also been observed among caged animals.

Dian Fossey in a remarkable decade-long study of mountain gorillas in Central Africa has recorded several instances of fully mature males ("silverbacks") killing infants belonging to primiparous mothers; in the best documented case, the mother subsequently copulated with the male who had killed her infant.

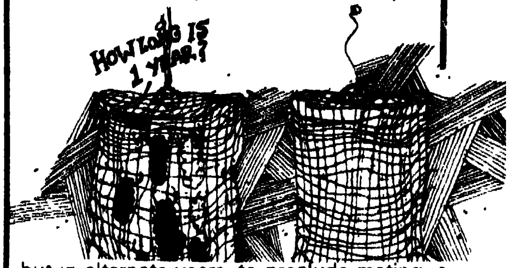
In India, such behaviour among langurs has been noted by several observers. Dr. Sarah Blaffer Hrdy of the Department of Anthropology, Harvard University (USA), who studied five troops of langurs around Mount Abu, observed infant mortality whenever a troop was taken over by a new male. The females, who had lost their infants, gave birth again within 27 months.

One explanation for such behaviour is that infanticide helps check population in crowded areas. However, Dr. Hrdy, writing in *The American Scientist* (January-February 1977), suggests that the behaviour is not pathological since it was directed at infants only. In fact, it is a result of what Darwin called 'sexual selection', that is, competition between members of one sex (typically males) resulting in fewer offspring for the less successful males. In the case of the langurs, the usurping male increases his own reproductive success at the expense of the former leader of the troop (presumably the father of the infant killed), the mother and the infant.

HOW TO DESIGN AN INSECT ZOO

A lot of fuss is being made about damage that may be done by lethal strains of bacteria that could be let loose by uncontrolled experiments in recombinant DNA. The critics fail to emphasise that even existing plants and animals can create havoc if transplanted to a new environment. The case of the prickly pear is well-known. The fire-ant, which administers a burning sting, probably introduced from Brazil or Argentina, has now become an unwelcome resident in nine southern states of the USA.

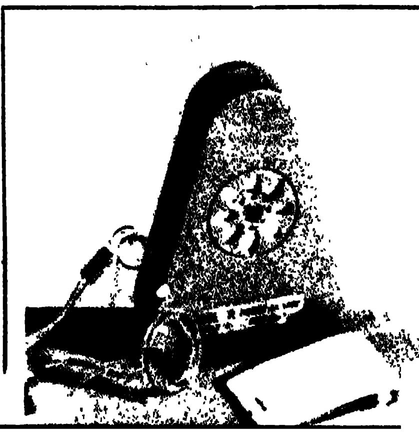
Naturally, when the Smithsonian Institution (USA) wanted to set up an insect zoo for educational purposes, the Animal and Plant Health Inspection Service of the US Department of Agriculture thought it should take a hand. It laid down that the males and females of risky insects like leaf-eating moths and plant-lice should not be imported in the same year but in alternate years, to preclude mating, reports *Bioscience* (January 1977). The zoo is designed to guarantee containment of the bugs. All cages are made of plexiglass with several layers of metal and rayon screening on top, treated with an antistick paint so that insects don't stick to the screen and crawl off when it is opened. The insect hatchery has heavy double doors separating it from the rest of the museum, and seals on all windows, doors and drains.


HOW LONG IS 1 YEAR?

THE BRAIN'S CHEMICALS COULD CAUSE ALCOHOLISM

Is alcoholism a disease? Medicine hasn't proved this as yet. Meanwhile, workers at Purdue University (USA), suggest that it could have an activator in the chemicals of the brain.

Robert D. Myers and Christine L. Melchior of the University's Laboratory of Neuropsychology found that rats which previously shunned alcohol could be made to drink by injecting tetrahydropapaveroline (THP), a compound derived from alcohol, into their brains. Before injection with THP, the rats drank mostly water and only traces of alcohol. After injection, the rats increased alcohol consumption as much as 20-fold, compared to the control group which received injections of brain fluid. Even six months after the THP infusions were stopped, the rats continued to drink large amounts of alcohol. The results indicate the possibility that some cellular defect in the alcoholics' brain may cause abnormal formation of



MAKES PURSE-SNATCHING DIFFICULT

The plastic alarm box goes inside a pocketbook or purse and the cord is fastened to your finger or wrist. When the cord is torn from the box, as it would be if a thief grabbed the purse, the buzzer in the alarm box comes on. Most thieves' reaction would be to drop the purse and run. Powered by a battery, the device costs $3 (Rs. 24).

THP at specific, sensitive sites. The only hope, the researchers say in a report in *Science* (29 April 1977), for a recovered alcoholic to avoid relapse is total abstinence.

MEASURING SCIENTISTS' OUTPUT

What is the measure of a scientist's productivity? The number of publications to his credit? And if so, what kind of publications?

The number of papers published is by itself no criterion. Since there are more than 50,000 scientific and technical journals in the world, a paper can ultimately get published if the author is determined says S. M Lawani in an article in *Bioscience* (January 1977). Nor is the journal in which they are published a reliable index. Even prestigious journals sometimes publish substandard papers. The rate of rejection too, varies greatly. *Physical Review* published about 80 per cent of submitted papers, and *Bioscience* (in 1975) about 59 per cent.

However, in general, quantity and quality are correlated, and scientists who achieve distinction are industrious. Of 41 American scientists who had got elected to the National Academy of Sciences, 11 had 300 or more publications each, the median number was 145.

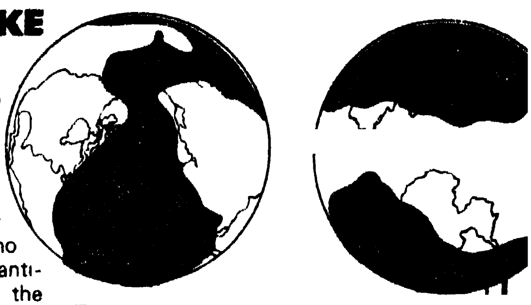
Of late, citation analysis has been used as a rating of a paper's quality. Most people agree that the number of times an author or paper has been cited in scientific literature is a valid measure of the quality of the paper or the author's contribution. References and footnotes cited in a number of journals are now published in the *Sciences Citation Index* and the *Social Sciences Citation Index*. The average number of citations for Nobel Prize winners in physics between 1955 and 1965 was 58, compared with an average of 5·5 citations for other scientists. Interestingly, prospective laureates were more highly cited than actual laureates.

However, there are some drawbacks to the method of citation analysis. It is the practice to cite only the first author (others being covered by the term "*et alia*") ; since most papers are multi-author papers, this may result in undervaluation of persons who are not first authors.

Other studies suggest that outstanding contributions are cited many times, while 50 per cent of all published papers are not cited at all. A paper of average quality may attract a large number of citations if it deals with a controversial subject or one in the research frontier.

OUR EARTH IS LIKE A TENNIS BALL

Like the two strips that make up the covering of a tennis ball, the Earth, too, is divided into two regions — one "high" strip and another "low" strip, according to D. I. Gough of the University of Alberta (Canada), who discovered this "remarkable antisymmetery" after transferring the contours of a Mercator map of the Smithsonian Standard Earth II geoid to a globe. The high strip runs across the north pole, with one lobe covering the western Pacific and most of Australia and another covering parts of the south Atlantic and south Indian Oceans (with a subsidiary extension over the South American Andes) The 'low' strip, which slices through Antarctica, has one lobe over the northern part of the Indian Ocean (including India and Asia) and the other lobe covers North America, the eastern Pacific and Brazil.

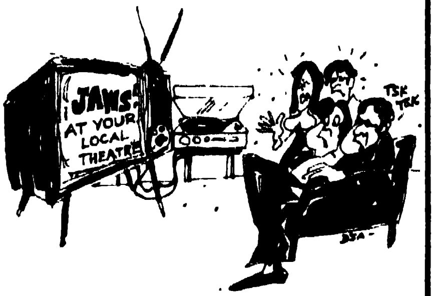


The coloured area represents the "high strip" as calculated by D. I. Gough

According to Gough, the 'high' and 'low' might correspond to the convection movements in the whole mantle, though the exact relationship is yet uncertain. If, however, the 'highs' could be related with the downward currents, Gough postulates, it could probably explain why the Pacific plate moves faster than the North Atlantic Ridge.

VIDEO DISC PLAYERS ARE COMING!

Sometime this year, video disc players are expected to be put on the US market by two world-wide organisations. You slip in a disc and see a recorded TV programme you would like to see again. The discs and the systems, however, are vastly different from the familiar 33⅓ and 45 rpm discs and current audio systems.


JAWS! AT YOUR LOCAL THEATRE
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One of the models plays a rigid 12 in (30 cm) diameter disc with 30 minutes playing time on both sides. The disc spins at 45 rpm. TV signals are encoded as minute depressions at the bottom of each groove. The discs have a vinyl base, topped with thin layers of metal, an insulating plastic and an oil lubricant that reduces stylus wear. The disc and the stylus together form an electrical circuit. As the slots spin past the stylus, tiny abrupt changes in the circuit capacitance occur. These changes de-tune an oscillator circuit to produce the TV signals.

Another model makes use of a radically different concept. Only one side of the aluminium disc is programmed. A low-power laser focussed to a one-micron spot strikes the bottom side of the disc and falls on a spiral track that consists of oblong bumps of varying lengths, with flat areas in between; the distance between the bumps varies with the encoded picture information. The flat areas between the bumps reflect part of the laser light through the optics to a light sensitive diode that detects the TV signal. The discs should last indefinitely, since there is no wear, the helium neon laser 'stylus' lasts a minimum of 10,000 hours.

If the brisk sales of video-cassettes are any indication, the video-disc players should be great hits.

TURNED INTO GOLD

It looks as if the dream of the alchemists — to turn base metals into gold — is coming true. But, in this case the material used is not a base metal but one costlier than gold — uranium.

The transmutation took place when experimenters of the Society for Heavy Ion Research in Germany were looking for a nucleus of one of the artificial elements of atomic number greater than uranium, that is, element 105. They bombarded a uranium target with uranium ions accelerated to 1·8 billion electron volts energy in the heavy ion accelerator called Unilac, located near Darmstadt. This energy is not enough to accomplish a complete fusion of the accelerated uranium nuclei with those in the target, but a certain exchange of protons and neutrons does occur. The result is that, one of the uranium nuclei becomes gold, and the other, element 105.

Whether the transmutation is worthwhile on a commercial scale would depend on the current prices of uranium and gold. In the last analysis, a nuclear scientist might have better uses for his uranium!

SLOWING DOWN SENILITY

Standard therapies involving drugs that dilate the blood vessels, and tranquillisers, yield little return in cases of senile dementia. M. H. Knisely of the Medical University of South Carolina (USA) had noted that constriction of vessels and arteries in ageing can cause red blood cells to adhere or aggregate and impair blood flow. He also pointed out that diabetes and alcoholism, among other conditions, can cause blood sludging. Arthur C. Walsh, a clinical assistant professor at the University of Pittsburgh (USA) and a psychiatric consultant at the Veterans Administration Hospital, Pittsburgh, who was aware of this work has now come to the conclusion that red-cell aggregation is the major cause of senility. Theories of arteriosclerosis attribute it to degeneration of the cells themselves or the onset of some virus that slows the flow of blood to the brain. Walsh also hypothesised that since severe emotional stress can cause stroke and heart attack, it is a contributor to vessel constriction and therefore blood sludging. He found that 22 out of 24 patients improved when given the anti-coagulant bishydroxycoumarin (" Dicumarel "). " Coumadin " was also effective. Psychiatry also helped the patients. Apparently what the drugs do is to reverse, or at least slow down, the senility, by breaking up the sludging and rejuvenating such cells.

VITAMIN E AND AGEING

The finding in 1972 that vitamin E could extend the lives of rodents by about 30 per cent has prompted gerontologists to see whether it could help humans. They suspect that vitamin E does the trick by protecting cells from the excess oxidation produced by free radicals (highly reactive chemicals in the cells), but they are not able to specify how exactly.

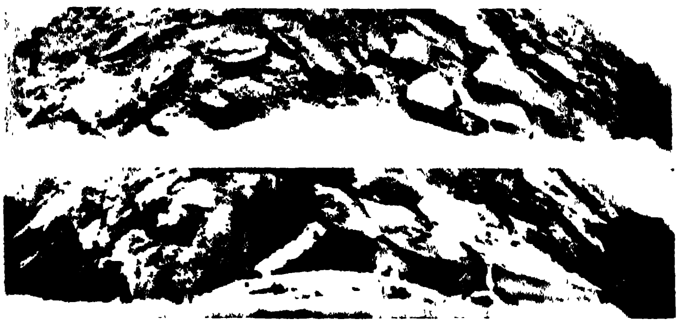
Experiments conducted by Lester Packer of the University of California, Berkeley (USA), and James R. Smith of the Veterans Administration Hospital, Martinez, California (USA), seem to confirm the anti-ageing effect of the vitamin. The vitamin appeared to double the usual life-span of human lung cells in the test-tube, compared with control cultures of lung cells. But, not being able to repeat these results — an essential condition in scientific research — they concluded that the calf serum (the fluid portion of blood) used in the first experiment for culturing cells was in some way different. They were not able to identify this factor in the serum, which might have interacted with vitamin E, because each lot of serum that scientists buy from biological companies is non-identical.

NEW TUNNELLING TECHNIQUE

Building a tunnel in soft ground is always a problem. If you have spent your holidays on the seashore with a bucket and spade, you will know basically what it means. The famous Thames tunnel built between 1825 and 1843 was the first tunnel to be driven for public traffic beneath a river. A UK firm, with the support of the National Research and Development Corporation of UK, has developed a new tunnelling process which aroused much interest within the civil engineering profession and at the international symposium 'Tunnelling 1976', held in London.

Tunnels often become necessary for underground railways and sewers in cities and often they have to be dug in unstable ground. One type of machine used extensively consists of an open-ended drum of steel having a rotating cutting head at one end and a number of hydraulic jacks around the inner periphery at the other end. The head is rotated to cut the ground at the front of the drum, while the jacks at the other end are pushed backwards against the end of the latest ring of tunnel-lining installed, thus pushing the drum forward into the ground being cut. The new machine developed with NRDC assistance has, in addition, a bulkhead at the tunnel face which contains a pressurised slurry of bentonite, a sort of clay which when mixed with water becomes a thixotropic jelly (becoming increasingly viscous with passage of time if left undisturbed).

This bentonite slurry is of advantage when ground water is encountered while tunnelling; otherwise, expensive compressed-air machinery has to be used to keep out the water.



Panoramic photo by Venera 9 (top) and Venera 10 (bottom)

BEHIND THE VEIL OF VENUS . . .

Soviet scientists are puzzled by two features in the pictures of the Venusian surface sent to them by the probes Venera 9 and 10 which landed on Venus in October 1975. Venera 9 photographs show boulders with sharp edges — even sharp points — suggesting that they were produced by the breaking of originally hard rocks. In the absence of liquid water to cause erosion, it is hard to explain the Venera 9 photographs, unless they can be put down to Venusian quakes. The Venera 10 photographs of the landing site show outcrops of hard material with pitted surface and rounded edges. These photographs are even more puzzling because the weathering cannot be caused by the gentle winds and the inert atmosphere of carbon dioxide — unless the atmosphere contains hitherto undetected active chemicals (possibly contributed by volcanic eruptions). The report is made in *Science* (20 May 1977) by C. P Florensky and his associates at the V. I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow.

The data from the landers indicates very low wind velocity (1 m/sec) as well as low atmospheric water vapour. Nor can meteoritic impact cause much weathering, because the atmosphere is so dense that no meteorite smaller than 30 m, if iron, or 60 m, if stone, can penetrate it.

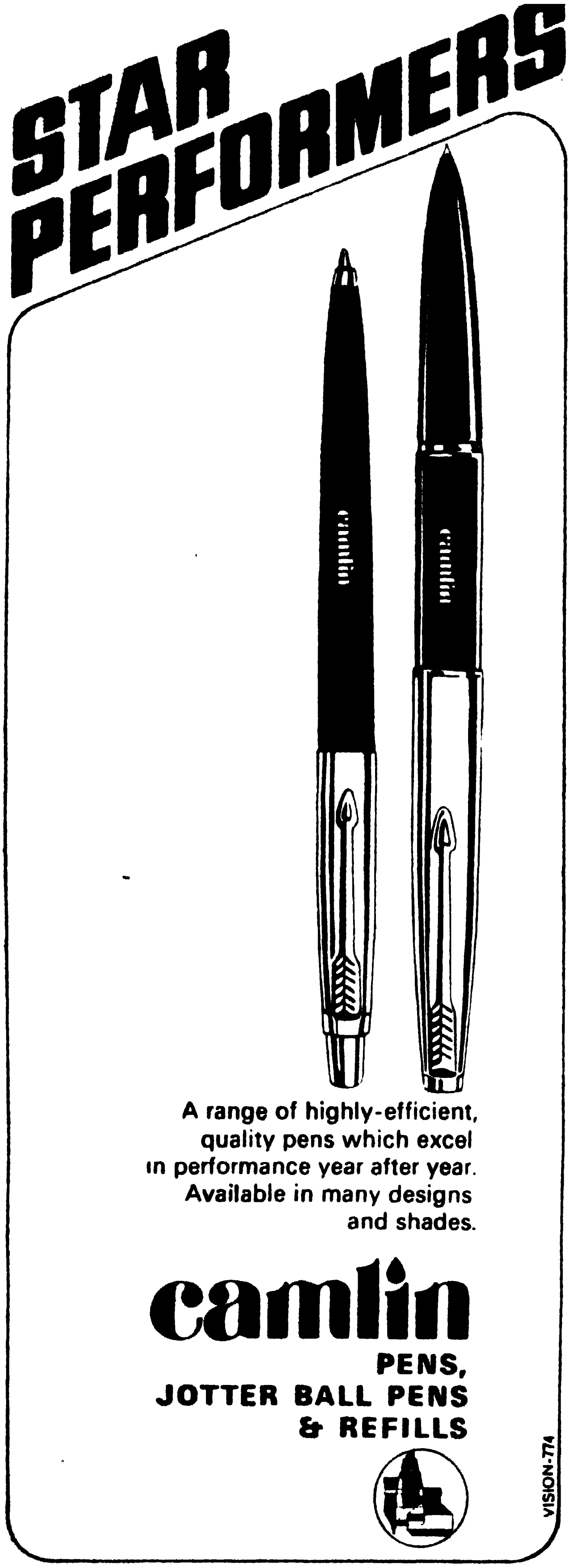
. . . A GIANT VOLCANO

However, radar pictures obtained by Richard M. Goldstein of Jet Propulsion Laboratory, Pasadena, USA, suggest the existence of a giant volcano, even bigger than Olympus Mon, the giant Martian volcano, which itself is five times the height of Mount Everest.

Named Beta, earlier researchers had seen the near-featureless bright spot on the northern hemisphere of Venus for nearly a decade without suspecting its true dimensions or nature. That this spot could be a volcano is implied by the way it polarises the radar beam, suggesting the rough surface of a volcanic region. Its width, about 700 km across, with a central depression or caldera about 90 km wide, dwarfs the 550 km width and 60 km wide caldera of Olympus Mon! By comparison, the entire volcanic island of Hawaii, even measured from the seabed, is puny, attaining about 120 km width at the maximum, with a 3 km wide main caldera. In altitude, however, Olympus Mon may still beat Beta, because Venusian gravity, which is two or three times the Martian gravity, and higher temperatures, would have produced plastic rocks, perhaps incapable of rising to great heights.

There are other features in the two-dimensional radar reflectance images of Venus — trough-like depressions and possibly a curved mountain range — which suggest largescale activity in the planet's crust in the past.

The supervolcano Beta (shown by arrow) on full-disc radar image of Venus



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SHRI HARI OM ASHRAM PRERIT DR. VIKRAM SARABHAI RESEARCH AWARDS FOR 1977

The Physical Research Laboratory makes **four awards** every year, called Shri Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards, from funds kindly donated by Pujya Shri Mota of Hari Om Ashram of Nadiad, Gujarat. These awards are to be made to Indian Scientists, who are not above 45 years of age (on 1st January of the year of the award), for original work in the following fields:

(1) Electronics and Telecommunications;
(2) Planetary and Space Science:
(3) Atmospheric Physics and Hydrology;
(4) Systems Analysis and Management.

Although the over-all work of the candidates would be taken into account, the work done by the candidate in India would be given primary consideration.

The candidate should have to his credit, at least one or more of the following achievements:

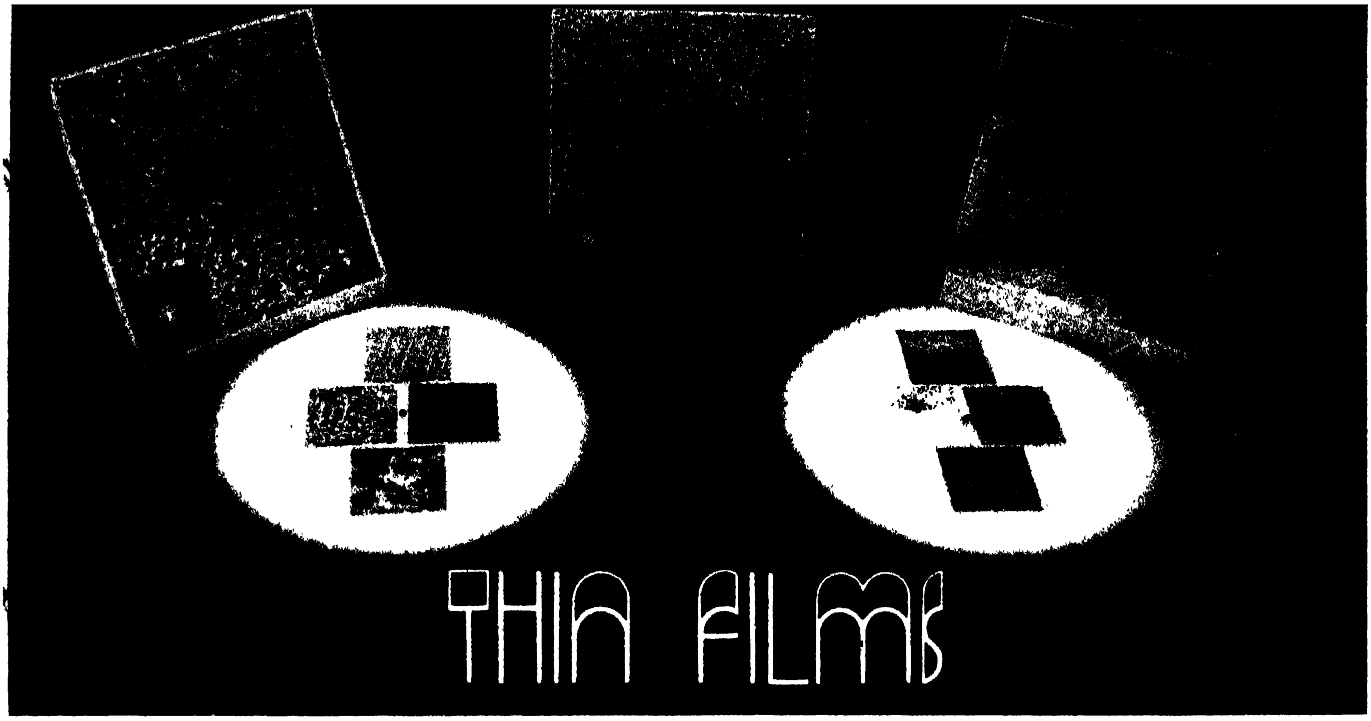
(a) Significant achievement in scientific research,
(b) Important and successful adaptation on new technology,
(c) Planning, development and implementation of systems in the context of science and technology.

The selections for the year 1977 will be completed by December 1977 and the awards presented on 12th August 1978.

Nominations are invited from responsible scientists. The last date for receiving nominations is **15th September 1977.**

Sponsors are requested to send a two-page note summarising the contributions and achievements of the sponsored candidate together with his/her bio-data, to Professor D. Lal, Director, Physical Research Laboratory, Navrangpura, Ahmedabad-380 009. Only nominations made for the year of the award would be considered.

More detailed information will be asked for by the Selection Committee, if considered necessary.



THIN FILMS

Electron micrographs and electron diffraction patterns of different materials show the arrangement of clusters of atoms in the early stage of growth of a material. At extreme right is shown the molecular chains of PVC. The chains are lined up in a systematic manner, made possible by a new technology developed at the Thin Film Laboratory of IIT, Delhi. This article outlines some aspects of thin film technology

K. L. CHOPRA

Miniaturised integrated optical circuits using thin film devices, akin to integrated electronic circuits, may soon bring about a revolution in communications technology. Thin film solar cells may enable many nations to tap the unlimited solar energy when the fossil fuel reserves run out. Thin film superconductors may carry electricity for hundreds of kilometres without any transmission losses. This is, of course, for the future. But the technology of thin films is already proving useful in such articles of daily use as artificial jewellery, anodised household appliances, Thermos flasks, magnetic tapes, goggles, coated optics of a camera or a microscope, Xerox machines, miniaturised thin-film resistors and capacitors and vidicon or electroluminescent panel/display devices. It is also finding application in basic sciences.

Indeed, the tremendous advances made by the science and technology of thin solid films in the last two decades have led to the creation of many new and full-fledged scientific disciplines. They include microelectronics, micromagnetics, thin film optics, integrated optics, amorphous (glassy) materials, thin film superconductivity, and surface science. The creation and understanding of the structures of thin films have been assisted by, and this, in turn, have been largely responsible for, the developments in such fields as ultrahigh vacuum technology, electron (transmission as well as scanning) microscopy, low/medium/high energy electron diffraction, and a variety of surface analytical techniques like Auger spectroscopy, secondary ion mass spectroscopy and electron spectroscopy for chemical analysis.

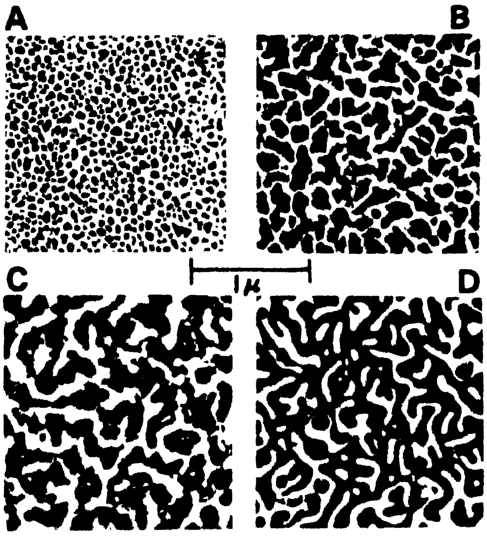
What is a thin film and what makes it so uniquely important in the study and application of solid state physics? A material having one of its dimensions about one micron (10^{-4} cm or 10,000 Å) or less is the geometrical description of a thin film. A commonly used gold or silver foil of a few thousand Angstrom thickness as obtained in our country by a beating process is *not* a thin film. Nor are those sprayed/varnished/painted/coated surfaces thin films, even though their thickness may be of less than a micron. (In fact, films so obtained are also of considerable technological interest in such areas as microelectronics and protection and passivation of surfaces. These films, generally thicker than one micron, belong to a new discipline called Thick Film Technology.)

What, really, characterises a thin film is the process by which it is obtained. The growth process is of fundamental importance to the science and technology of thin films, since it largely determines the film's novel structural behaviour and properties. A thin film may then be scientifically defined as a thin two-dimensional material — born of an atom (molecule)-by-atom (molecule) condensation process. The condensation is generally achieved from the vapour phase of a material.

It may be worthwhile now to examine the process of condensation of a beam of vaporised atoms/molecules intercepted by a solid surface called substrate. The vapour atoms interact with the surface atoms of the substrate via *Van der Waals forces* and get physically adsorbed. The adsorbed atoms (called " adatom ") soon lose the velocity component normal to the surface, but retain the velocity component in the plane of the substrate. The motion they execute is a random walk. The adatoms encounter others of the same species and bond with them to form a cluster. The volume cohesive forces due to bonding would increase with the increasing number of adatoms in the cluster, but, at the same time, the disruptive forces due to the presence of dangling or dissatisfied bonds at the free surface of the cluster would increase. There, thus, exists a critical size at and beyond which the cohesive forces are decisive in bringing about the chemical adsorption of the stable cluster. This process of nucleation yields three-dimensional randomly distributed islands which grow further by the addition of new atoms from the vapour phase as well as by surface dif

The occurrence of such three-dimensional islands in ultra thin films of metals, insulators and semiconductors has been well-established by electron microscopy. The growing islands coalesce into one another by surface and volume diffusion forming a network which fills gradually to form a continuous film (see Fig. 2). The solid state process of coalescence as seen with an electron microscope is very rapid in the case of metals; it appears as a liquid-like coalescence process. In summary, the thin film is born of a nucleation process and grows by a process of coalescence (sintering) between microscopic clusters. The coalescence phenomena have a profound effect on the structure and properties of the resultant film since recrystallisation, grain growth, orientation changes, incorporation and removal of defects, etc occur as a consequence of coalescence.

Fig. 2 A sequence (a) to (d) of electron micrographs of Ag films of 100, 105, 110, and 115 Å average thickness, respectively, evaporated onto NaCl at 100°C, demonstrating the rapidity of the coalescence process leading to a network structure



A film thus represents the *ab initio* birth of a material. But, what is perhaps the most significant aspect of the birth process is that it (and hence the corresponding microstructural details) can be modified drastically by changing the conditions of deposition like the chemical nature and temperature of the substrate, rate and angle of deposition, energy and species of the vapour atoms, nature and degree of vacuum, etc. These parameters affect the mobility of the adatoms, and the size, distribution, and coalescence characteristics of the islands.

Changing the conditions of deposition

What are the major advantages of changing the conditions of deposition? By controlling the temperature of deposition it is possible to nearly immobilise the adatoms on the substrate. Consequently, they have little chance to grow together in a harmonious and ordered manner (which is so characteristic of a lot of matter found in nature). The result is an amorphous or glassy state (devoid of long range order). At the other extreme, the adatoms can be given high mobility leading to the formation of matter in a granular form with a regular arrangement of atoms (polycrystalline). If the surface happens to be a single crystal (with regular and periodic arrangement of atoms over the whole surface), the periodic forces of cohesion induce an oriented growth (called epitaxy or " arrangement on") in the film with a geometrical arrangement of atoms which is well-defined and correlated (but not necessarily the same) with that of the substrate atoms. Most significantly, a large number of elemental materials, and most of their alloys and compounds can be obtained in amorphous, polycrystalline or epitaxial (often, though wrongly, called single crystal) forms. Excellent examples of interest are: W, Mo, Ta, Fe, Cu-Ag, Ge, Si, Ge-Te, and Ga-As. Fig. 3 illustrates this point in the case of sputtered molybdenum films. What is noteworthy is that the single crystal films can be obtained at deposition temperatures well below the melting points of the materials and also the normal temperatures required for the growth of bulk crystals. Thus, single crystal films of gold, silver and copper can be obtained at or below room temperature, in contrast to about a thousand degrees required for the formation of bulk single crystals of these metals.

In the early stages of growth, the films consist of islands and empty channels and are thus porous on a microscopic scale. Even on coalescence of the islands, the misfit of geometrical boundaries leads to the freezing-in of a host of defects such as vacancies, vacancy clusters, dislocations and stacking faults. The porosity as well as the concentration of the various defects can, however, be controlled and modified over a very wide range. One can prepare films such that the effective area for gaseous adsorption and catalytic reactions is hundreds of times larger than the simple surface geometrical area. Further, it is not uncommon to freeze-in several atomic per cent vacancies and $\sim 10^{14}$ lines/cm^2 of dislocations in films deposited at room temperature. The concentration of induced defects can be several orders of magnitude larger than that frozen in a bulk crystal by such harsh treatments as cold working and irradiation by energetic particles. An electron micrograph (Fig. 4) of a silver film illustrates the variety and high concentration of defects.

A crystal has a unique and characteristic geometrical arrangement (lattice) of atoms; the stable arrangement is determined by minimum energy consideration. Since interatomic forces in small clusters can now be significantly modified with surface, strain, electrostatic and magnetostatic (in case of magnetic materials) energy, the energy balance may favour the formation of new and unusual arrangement of atoms in small clusters having a few to tens of atoms. This metastable arrangement, once produced, could, in principle, propagate. The phenomenon has in-

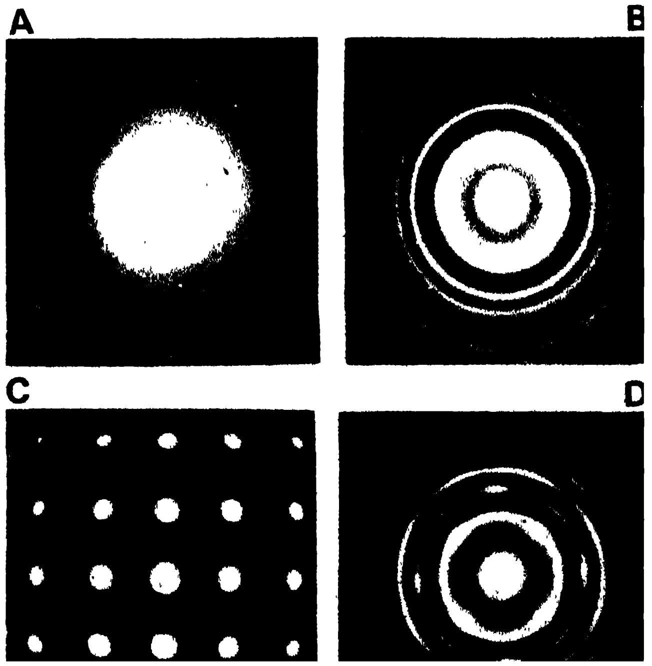


Fig. 3 Electron-diffraction patterns of 500 Å-thick Mo films ion-beam-sputtered onto NaCl at (a) 23°C, amorphous; (b) 250°C, fcc metastable; (c) 450°C, fcc metastable single crystal; (d) fcc annealed to 675°C in vacuum, fcc + bcc Mo

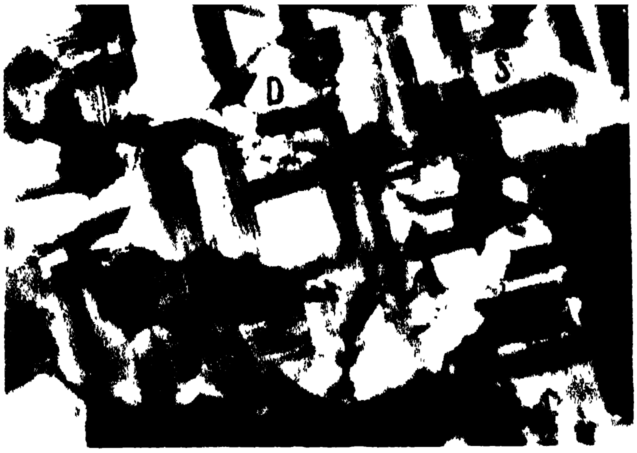


Fig. 4 A typical transmission electron micrograph of 1,000 Å-thick epitaxial Ag film evaporated onto cleaved NaCl at 200°C, showing stacking fault (S) fringe arrays, dislocations (D), and other defects

deed been amply demonstrated in a large number of metals, alloys and compounds. Based on his extensive work, the author has formulated rules for the existence/occurrence of these new and unusual metastable phases of materials. As an example, semiconducting sulphides, selenides, tellurides, arsenides and phosphides of a number of metals may be stabilised in either the cubic or hexagonal phase; some properties of the two phases are quite different. For instance, only hexagonal cadmium sulphide is useful for surface wave devices, whereas cubic phases of the same material find application in other devices.

The solubility of one material in another is governed by a number of physical rules. Thus, two materials can be dissolved into each other to form alloys or compounds only for specific ranges of composition. The atom-by-atom condensation process of thin films can relax the solubility criteria so that literally any material A can be made to mix with any material B in some composition range. If A and B are soluble in bulk, their solubility range can be extended, quite often to the entire composition. A number of seemingly unthinkable materials like ZnS-MgF_2, $Pb_x Hg_{1-x}S$, metallopolymers, Cu-Ag, etc can thus be formed. In special cases, where the material A tends to become amorphous, and the atoms of material B have a high mobility, their mixing results in an island structure of B studded with clusters of A. This ceramic-metal microscopic composite is called " Cermet " and is of considerable technical interest in the manufacture of thin-film resistors because of the possibility of obtaining a very wide range of resistivities and temperature coefficient of resistivity (TCR) in these materials.

Besides the microstructure, the surface topology of a film can also be modified in numerous ways. Surfaces of atomic smoothness at one extreme, and very rough and columnar (like the lunar surface) at the other can be obtained in the same material by changing the deposition conditions (see Fig. 5). Thus, films of the same material with a whole range of surface, electronic and optical properties can be created.

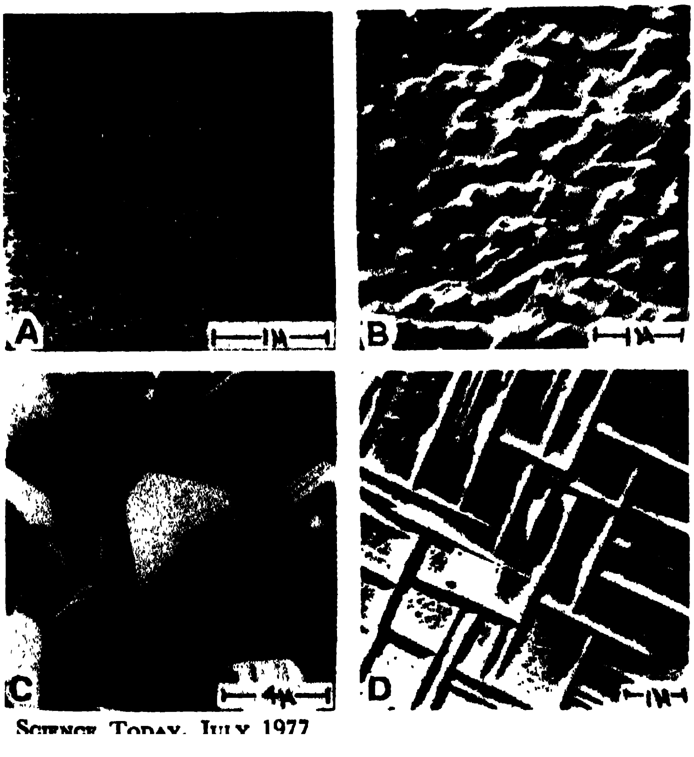
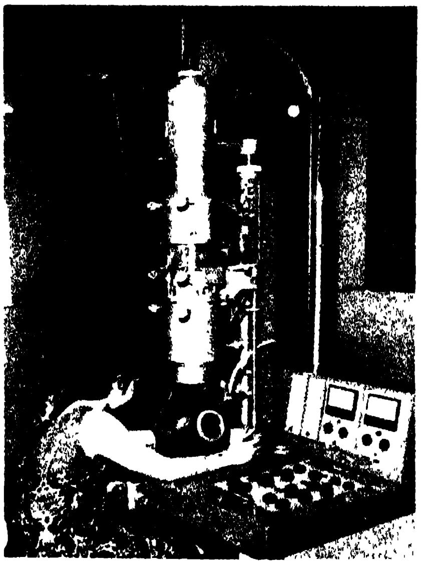


Fig. 5 Electron micrographs of a variety of surfaces of different films: (a) atomically smooth, 1,000 Å sputtered Au film on NaCl; (b) a rough Ag film evaporated on mica at 300°C, roughness caused by a deposition rate exceeding 3,000 Å/min; (c) a faceted growth with platelet crystals in a 3-µ—thick $Bi_2 Te_3$ films sputtered on glass at 400°C; and (d) a rod-like crystallite growth of polyoxymethylene film on (KCl [110] direction shown by an arrow) from nitrobenzene solution held at 120°C

The innumerable unnatural and unusual structures and microstructures that can be obtained in thin films of a material are beyond the imagination of a solid state physicist or a materials scientist working with bulk materials. This alone should justify our insistence on defining a thin film not merely in terms of its dimensions but also in terms of its mode of creation.

The unusual structures of films represent thermodynamically non-equilibrium states. But, these structures have a long-term stability under controlled environmental conditions and also provide the scientist with unusual physical phenomena of enormous academic and technological interest. It would not be an exaggeration to state that the future technological revolutions are critically dependent on new materials with high strength, high elasticity, high superconducting transition temperature, high dielectric breakdown, high permeability, high optical transmission, etc. However unrealistic it may seem now, thin films of some materials have already provided the materials scientist considerable encouragement in the search of such exotic and uncommon materials.



A transmission electron-microscope at IIT, Delhi—an invaluable aid to studying the structure of thin films

Applications

Let us now discuss some major applications of thin-film materials. The creation of a large concentration of structural defects increases the mechanical (tensile) strength of a thin film. Films of metals having hundreds of times greater strength than that of the bulk have been obtained. Larger internal stresses (~10^9 to 10^{10} dynes/cm^2), comparable to the yield strength of most

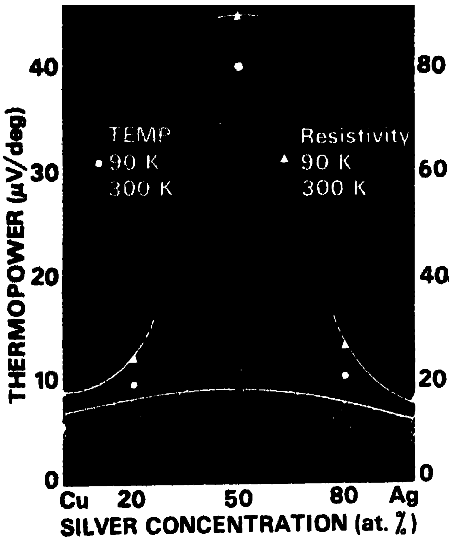


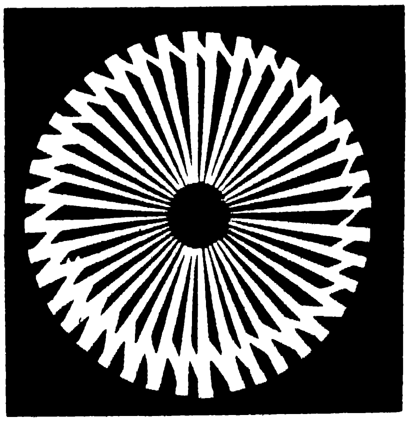
Fig. 6 Thermopower and resistivity of as-deposited/unannealed (at 90 K) and annealed (at 300 K) $Cu_{1-x}Ag_x$ films of various compositions

bulk metals, are known to develop in thin films during their growth. These have profound effects on the electrical, magnetic, superconducting and semiconducting properties of films. On destruction of the long range order, amorphous films also assume significantly different electronic, magnetic and optical properties. Fig. 6 illustrates how the resistivity and thermoelectric power of Cu-Ag films of various compositions increase by factors of about 100 and 25, respectively, in the amorphous state. It should be noted that copper and silver do not mix with each other in bulk but can form metastable crystalline as well as amorphous alloys in thin films. The large value of the thermoelectric power in disordered metal alloy and semiconductor films is exploited in the construction of sensitive and fast bolometers or thermopiles. The thermopile shown in Fig. 7 consists of 40 Cu-constantan thermocouples developed in our laboratory and can measure a millionth of a degree temperature difference between the hot and cold ends. Individual thermocouples can record temperature changes occurring in less than 10^{-8} sec. A whole array of fast thermocouples is being used for commercial and military applications in advanced countries as a night vision device for producing infrared images of objects in the dark and for thermography of objects.

The high resistivity and the strong photoconductivity of selenium films form the backbone of the xerographic process which has caused a revolution in information dissemination. Some amorphous semi-conducting alloys/compounds of selenium with sulphur or arsenic have the useful property that, on irradiation with suitable light, the image of an object can be imprinted on a film of the material in the form of changed optical transparency. This change can, of course, be " read " and then " erased " by a thermal bleaching process. We thus have an optical memory system for storage and retrieval of information. Holographic memories and gratings have, in fact, been created on a commercial basis this way. A new development of considerable impact is that the modifications in the transparency of some amorphous films on irradiation can be " developed " chemically so as to produce either a " negative " or a " positive " image of the object. The physical and chemical basis of image formation is presently being investigated in our laboratory. Technologically, it may constitute a new, simple and economical process for high resolution photolithography (for applications in integrated circuit technology) and photography. The fact that the image is produced in a thin film of a thousand Angstrom thickness and of grains with atomic dimensions ensures an image resolution of ~100 Å or less. The reproduction of a high resolution mask in a 500 Å thick amorphous germanium-based film deposited in vacuum or glass is shown in Fig. 8.

Single crystal and polycrystalline ferromagnetic films have been prepared under a wide variety of conditions. The magnetic properties of such films are largely determined by the magnitudes of the magnetic anisotropy present in the film. Polycrystalline films of metal iron alloys (81 per cent Ni, 19 per cent Fe, sometimes known as 'permalloy') have the unique magnetic property that the direction of magnetisation is confined to the plane of the film if the demagnetisation field is larger than the anisotropy field. In such a case, the magnetisation can be rotated and reversed at very high speeds (under application of magnetic fields of a few Oersteds) — a phenomenon which is the basis of the exploitation of Ni-Fe films for magnetic memory devices in a computer. If, on the other hand, the anisotropy field is much larger than the demagnetisation field, as is the case in the crystalline as well as amorphous alloy films of Gd-Co, Gd-Fe, Gd-Mo, Co-P, Tb-Ni, Gd-Co-Au, etc, the film can be magnetised in the form of cylindrical domains (called magnetic bubbles), a few microns in diameter, perpendicular to the plane of the film. Packed to a density of 10^6 to 10^7 per cm^2, the bubbles can be moved fast at speeds up to 10,000 cm/sec by the application of small magnetic fields. One can store, transfer or retrieve information in such bubbles. The high density of bubbles coupled with a high speed of access (10^{-8} to 10^{-9} sec) make magnetic bubble devices very attractive for computer memory applications (see Science Today, March 1973, p. 29). Information may also be magnetically written in crystalline or amorphous films of Mn-Bi and Gd-Co and read out magneto-optically by utilising the large effect of Faraday rotation (the rotation of the plane of vibration of polarised light on traversing an isotropic transparent medium placed in a magnetic field, possessing a component in the direction of the ray is known as Faraday rotation; the same phenomenon applies also to other forms of electro-magnetic radiation) in these films. With a packing density of 10^6 bits/cm^2, the writing field in a Mn-Bi film is about 10 Oe and the read-out rate around 10^9 bits/sec at 1 mW He-Ne laser power level.

Fig. 7 Thin film thermopile consisting of 42 $Cu/Ge_{90}Cu_{10}$ elements capable of measuring temperature ~ 10^{-5}K. (Developed at the Thin Film Laboratory, IIT, Delhi)



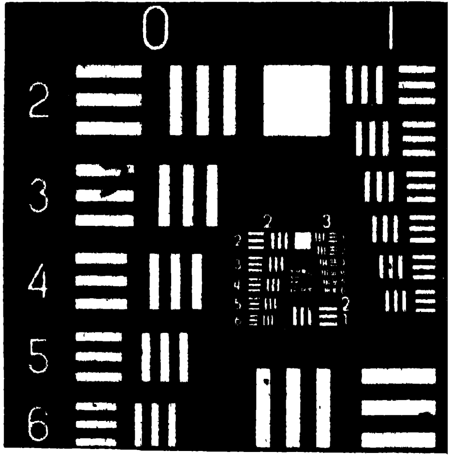


Fig. 8 Resolution pattern reproduced by photolithography on an amorphous $Se_{75}Ge_{25}$ thin (500 Å) film at the Thin Film Laboratory, IIT, Delhi

A class of amorphous magnetic alloys called magnetic glasses has created considerable interest in recent years. Coupled with high mechanical strength, high corrosion resistance and

THIN FILM DEPOSITION TECHNOLOGY

Thin films are prepared by a variety of deposition techniques. They basically involve two physical processes: (1) the production of a beam of vaporised atoms and/or molecules of the desired material (source), and (2) the condensation (deposition) of the beam on the substrate at an " effectively " lower temperature (or higher supersaturation) than that of the beam. The deposition techniques are broadly divided into two categories: (1) Physical vapour deposition, and (2) Chemical vapour deposition.

Physical vapour deposition

The most common method here is thermal evaporation, which involves heating of a given material directly or indirectly to a temperature high enough to form a high atom density vaporised beam (typically 10^{16} or more atoms per cm^2 per second), with a sufficiently high vapour pressure. The material may be heated by placing it in a suitably shaped and electrically heated filament, basket or boat made of a high melting point and high resistivity metal such as tungsten, molybdenum or tantalum. To prevent chemical reaction with the material, the vapour sources (as these are called) are coated with ceramics such as alumina, zirconia, silicon carbide, etc. Alternatively, one may employ indirectly heated crucibles made of quartz, alumina or zirconia.

Thermal evaporation techniques are simple, clean and easy to control. Thermal evaporation can also be achieved by heating materials with a high-power CO_2 laser beam, or an energetic electron beam. In the electron gun, the electrons are generated by heating a tungsten wire and are then accelerated by a ten kilovolt potential. By employing a variety of electrostatic and/or magnetic focusing techniques, the powerful electron beams can be used to melt literally any material in almost a fraction of a second by dumping all the kinetic energy of the electrons into the material under bombardment. The sophisticated electron guns are thus very useful for high-rate evaporation of difficult-to-evaporate materials. Moreover, it is very convenient to employ more than one vapour source to enable mixing of different materials to form alloys/compounds of desired compositions.

To eliminate the influence of ambient gas atoms on the vaporised beam of a material, it is necessary to perform the thermal evaporation in a vacuum system at sufficiently low pressure; such a system would ensure that the number of collisions of gas atoms with the vapour atoms or substrate is insignificant. Depending on the material to be evaporated and its sensitivity of reaction to the gas atoms, pressures of 10^{-6} Torr or less (10^{-10} Torr) are commonly used. A typical vacuum system fabricated in our laboratory for the purpose is shown in Fig. A. Such a system requires a host of gadgets to measure the pressure, the rate of evaporation and other physical conditions prevailing on the substrate. The rate of evaporation of a material is conventionally measured by measuring the ionised part of the beam as a current or by using a quartz micro-balance (a quartz crystal oscillator, the frequency of which changes on the addition of atoms to its surface).

Another powerful technique often employed to produce a vaporised beam is by removing the atoms/molecules of a material by bombarding its surface with high momentum ions of inert gases such as argon. This technique called " sputtering " (Fig. C) has many variants and, in principle, involves a high voltage direct current (or high frequency AC) discharge in a chamber filled with gas at a reduced pressure (of the order of tens of microns). The positive ions in the discharge are accelerated by an electric potential and allowed to bombard the material (target). The atoms of the material are removed essentially by a momentum transfer process and proceed outwards in all directions. Sputtering yields a diffuse vapour beam but one may obtain directed sputtering at low pressures by means of an ion beam.

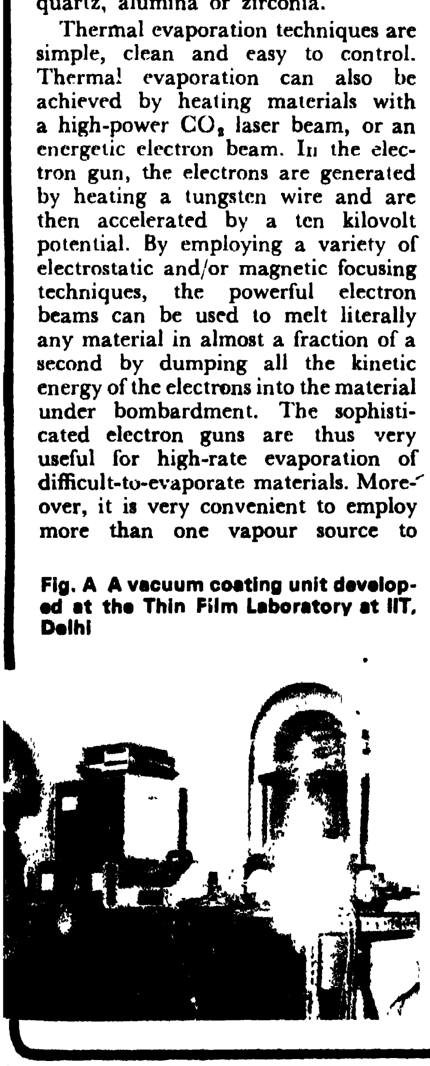


Fig. A A vacuum coating unit developed at the Thin Film Laboratory at IIT, Delhi

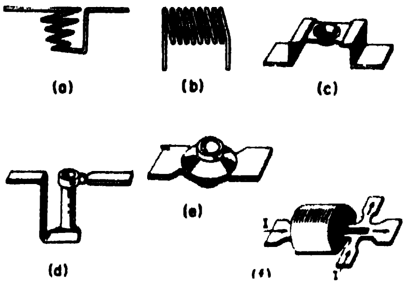


Fig. B Some thermal-evaporation sources : (a) basket, (b) spiral, (c) dimpled boat, (d) howitzer, (e) crucible heater, (f) dual boat, flash evaporation source

Chemical vapour deposition

This category encompasses a very wide variety of chemical processes. Basically, any chemical reaction, or decomposition of a chemical (say, at high temperatures in which case it is referred to as pyrolysis) yields a product in vapour form. The decomposition may be effected by an electrochemical process (in which case it is called electroplating) or electrolysis (for metals), or anodisation (involving the reaction of oxygen ions with a metal). Although it is difficult to control the rate and purity, chemical vapour deposition is the cheapest technology for mass production of thin films. For example, pyrolysis of SiH_4 (silane) is a commonly used commercial process for the production of epitaxial silicon wafers for integrated circuit technology. Deposition of thin film of very high purity is industrially achieved by the process of electrolysis. And, aluminium oxide films (of different thickness and, hence, different colours) can be obtained by the wet anodisation process. Chemical reaction of two reactants at a high temperature substrate is the basis of the spray techniques used in the production of thin film CdS solar cells and conducting glass. Ingenious exploitation of suitable chemical reactions at or below room temperature, or adsorption of chemical constituents (particularly chains of a polymer dissolved in a solution) yield very interesting thin films by the so-called " solution growth techniques ".

What about substrates? The physical and chemical conditions of the substrate, needless to say, play a very important role in determining the structure of films. The chemical nature and the surface characteristics of a substrate are, however, dictated by the particular needs of a thin film. Single crystal substrates of NaCl, KBr, mica, MgO, sapphire, Ge, Si, etc, are used for epitaxial growth studies. Inert glass and ceramic substrates are commonly used for measurements of the physical properties on polycrystalline and amorphous films.

Numerous techniques also exist for the measurement of the thickness and surface profile of films. Such techniques include weighing (with a microbalance), interferometric, spectrophotometric and stylus (amplified movements of a diamond needle) methods. (For further details, the reader may consult the author's book *Thin Film Phenomena*, McGraw-Hill Book Company, New York, pp. 83-138.)

Fig. C A radio frequency sputtering unit developed at the Thin Film Laboratory at IIT, Delhi

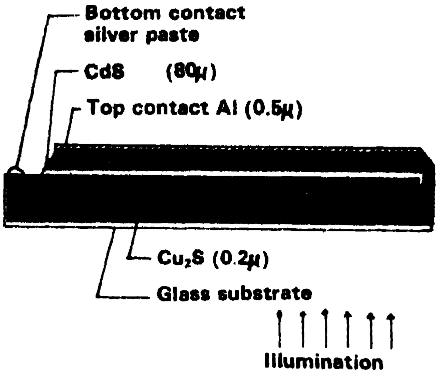


Fig. 9 Cross-section of a thin-film Cu_2S/CdS solar cell fabricated at the Thin Film Laboratory, IIT, Delhi

high magnetic permeability, some of these alloys (such as $Fe_{80}B_{20}$) have as small a coercive field (the magnetic field to which a ferromagnetic substance undergoing a hysteresis cycle must be subjected in order to demagnetise the substance completely) as 0·04 Oe and vanishingly small hysteresis losses (B-H loop). These materials, already available in thick foils, will, no doubt, have considerable impact on future electrical industry.

Achieving superconductivity at high temperatures (liquid air, if not room temperature) continues to haunt as well as inspire solid state physicists. On the basis of our existing knowledge, it may be speculated that thin film materials are the answer to high temperature superconductivity. Further, since superconducting currents are confined to the surface layer of a material, the electrical and electronic applications of superconductivity will be essentially based on thin films. Surprisingly, the most ordered quantum state (superconductivity is now well established as a macroscopic manifestation of the quantum effects) of a superconductor occurs *only* in the highly disordered and amorphous states of *some* materials such as Be and Cu-Ge. It has been observed that in amorphous films of tungsten and molybdenum, the superconducting transition temperature is considerably enhanced.

Of course, some of the most significant fundamental understandings of the phenomenon of superconductivity have resulted from the study of thin films. Among the major developments are the discovery of ' Cooper pair ' (pair of electrons) and the tunnelling of Cooper pairs between two superconductors connected by a very thin (tens of Angstroms) non-superconducting barrier film giving rise to a supercurrent. Besides providing a new generation of electronic switching devices (cryotrons), the Josephson effect of Cooper pair tunnelling and the related quantum interference effects offer us the most precise voltage standard and the values of some fundamental constants.

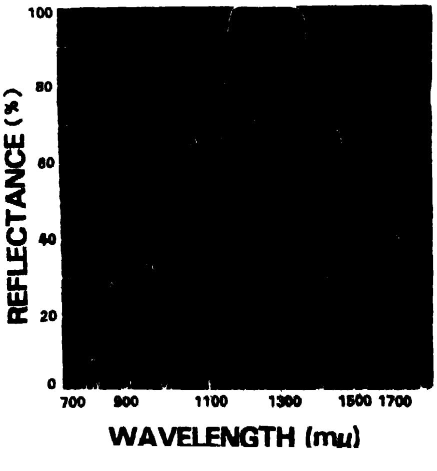
Epi layer (of silicon) is such a common name in the semiconductor world that both the scientist and the industry have forgotten that it represents the most significant commercial application of thin film technology. Epitaxially grown and well-oriented films of a number of semiconducting compounds find specialised applications in piezoelectric (surface wave), heterojunction, photoconducting, infrared and luminescent devices. The versatility of these electronic devices is enhanced by the possibility of alloying different thin film semiconductors to yield materials having a wide range of electrical, optical and physical constants. Thus, for example, we have prepared variable composition alloy films of PbS and HgS so that the optical band gap can be varied from 0·1 to 1·2 eV. This enables the fabrication of remote sensing detectors operating from visible to far infrared radiations.

Solar cells

Heterojunctions are currently the subject of extensive investigations for application in devices such as lasers and solar cells. Economical conversion of solar energy into electrical energy by photovoltaic mechanism will, no doubt, be possible with the help of large area thin-film solar cells made with polycrystalline semiconducting films. One of the leading contenders in this quest is the cheap thin-film $CdS-Cu_2S$ heterojunction solar cell. It is not difficult to make such a solar cell of several square centimetres area and with conversion efficiency up to 8 per cent. But the real challenge is to preserve the life of the cell. Conventionally, such a cell consists of about 20 micron thick evaporated CdS film and 2000 Å thick Cu_2S film (obtained by chemical conversion of the surface layer of CdS). The Cu_2S film is unfortunately very susceptible to degradation due to the presence of a gradient of copper and/or oxygen. By the processes of oxidation, diffusion or electrochemical reaction, the Cu_2S continuously transforms itself to several other lower forms, Cu_xS, which are not suitable, optically as well as electrically, for efficient solar energy conversion. The solution to the problem lies in producing Cu_2S of exact composition. Alternatively, the structure may be stabilised with the help of an appropriate impurity. We have resolved this problem to a large extent in our laboratory by creating Cu_2S film by a solid state reaction between CdS and CuCl films (see SCIENCE TODAY, April 1977, p. 22). The structural stability and physical coherence of both CdS and Cu_2S films are further improved by special dopants. The solar cell so obtained is shown schematically in Fig. 9. We have obtained cells with four per cent efficiency and negligible degradation over a period of six months. Although there is a long way to go before a commercially viable thin-film CdS solar cell becomes viable, the versatility of thin-film techniques makes it a promising possibility.

The development of thin-film technology owes a great deal to the demands of the optical instruments industry, particularly the application of optical film coating to mirrors and interferometers. As we know, light incident on the surface of a glass is partly reflected and partly transmitted, the refractive index of glass being different from that of the surrounding medium. Thus, a considerable amount of light in a multi-component optical instrument is wasted by reflections at each glass-air interface. Both the brightness and contrast of the optical image can be improved by eliminating or reducing such unwanted reflections. Further, in some optical instruments, it may be desirable to transmit or reflect only selected wavelength(s). Another example is that of amplification of light in a gas laser which depends on multiple reflections of suitable wavelength(s) from nearly ideal mirrors (reflection interference filters). Optically coated lenses and mirrors improve the optics considerably in such cases. The cellulose film in a projector is saved from melting by the use of a specially coated lens capable of transmitting only the visible and not the infrared (heat) radiations from the projector lamp. By choosing films of suitable optical characteristics, it is even possible to regulate the inside

Fig. 10 Observed reflectance spectrum of a 20 period ZnS — MgF_2 film designed by Yadava *et al* (*Thin Solid Films*, **21**, **297**, **1974**)



temperature of artificial satellites.

How does the optical coating work? It is based on the simple phenomenon of interference between light waves reflected from the front and back surfaces of a single film or a system of multilayer films. The phase difference between two waves depends on the angle of incidence, thickness and the optical constants (refractive index and extinction coefficient) of the film or its equivalent. By adjusting the optical thickness (a product of the geometrical thickness and the refractive index), waves may be allowed to interfere constructively or destructively at one or more wavelengths (as in the case of multilayer structures). One can design and construct a thin-film multilayer structure which will yield nearly 100 per cent reflectance or transmission at one wavelength (with half width as narrow as a fraction of an Angstrom) or a band of wavelengths covering hundreds of Angstroms. The characteristics of one such reflection filter are shown in Fig. 10.

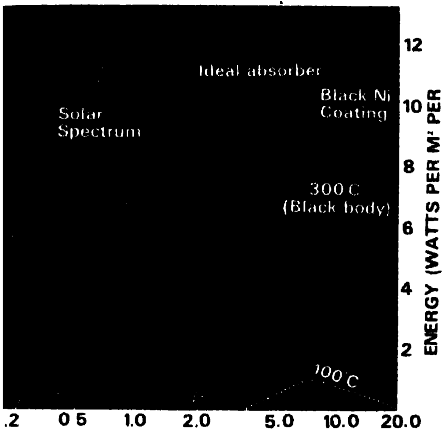


Fig. 11 Spectral distributions of solar and blackbody (at 300°C and 100°C) radiation. The dotted and solid curves show the spectral reflectance of an ideal photothermal converter and a black nickel coating, respectively, developed at the Thin Film Laboratory, IIT, Delhi

The efficient conversion of solar energy into thermal energy requires a surface which absorbs solar radiation below about 2 microns to get heated, but does not re-emit (low emissivity) radiations in the infrared (beyond about 2 microns). This calls for "selective coatings" which are readily achieved with films of a mixture of a metal and a dielectric semiconductor (eg, black chrome/nickel/iron consisting of the metal and its oxides), tandem or superposed films of a low band gap semiconductor and a metal, or an interference type of multilayer (steel/Al_2O_3/Al) structure. The optical characteristics of one such selective coating, approaching an ideal behaviour, are shown in Fig. 11. Selective coatings offer the best hope of utilising the low-grade solar energy for thermal conversion.

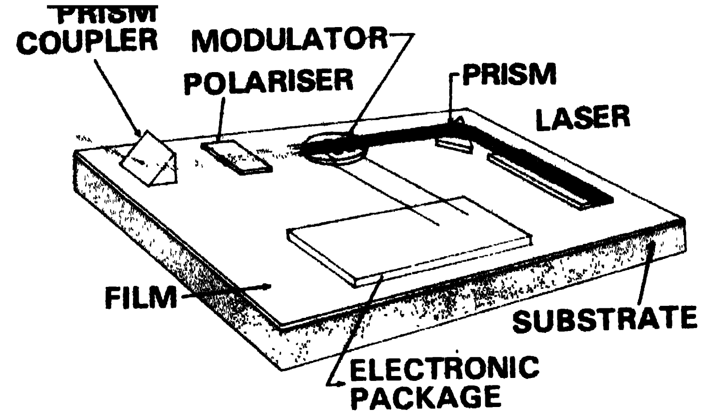


Fig. 12 Complete optical circuit made entirely of thin film devices may soon be fabricated on a substrate having an area of only a few square centimetres. In this circuit the light is generated by a tiny laser and directed around a corner by a prism, where it enters a magneto-optical switch. Signals from the small electronic package modulate the light, which then enters a polariser. The light wave, now modulated by the signals, can be coupled into a glass fibre and transmitted many km away for communication purposes. (P. K. Tien, "Integrated Optics", *Scientific American*, April 1974, p. 28)

The action of a lens, a prism, or a waveguide can be imitated by varying the refractive index spatially in any intricate geometrical fashion; the latter is achieved by varying the thickness or composition of a film. Similarly, anisotropic optical absorption characteristics can be built in films of suitable materials to obtain effective polarisation action. These micro-miniaturised optical components, together with thin-film lasers and optical modulation techniques, have ushered in the new era of "integrated optics" — a very convenient and desirable marriage of integrated circuits and thin-film optics. With integrated optics, scientists hope to achieve a major breakthrough in using the very large bandwidth optical communications network. This subject, however, is still a laboratory curiosity, but the progress is very encouraging. An example of an integrated optics device is shown in Fig. 12.

Needless to say, the small thickness of a film is no less important than its structure. A lot of work of fundamental interest in thin films is based on the thickness or "size" effects. The confinement of electrons (conduction as well as hot) within the surfaces of a film brings in a new dimension to our understanding of the electronic properties of surfaces. Moreover, it is the small thickness of dielectric and semiconducting films that allows us to study high field electron transport and optical effects. Thin-film resistors and capacitors of extremely high precision (a few parts per million) are now produced for use in analog digital conversion. As already mentioned, the thickness also plays a major role in determining the superconducting properties of films.

I should like to state here that most of the examples of thin films applications cited above have been taken from the work of my laboratory and, therefore, represent a somewhat biased interest. A number of other significant developments have not been touched at all for want of coherence and space. Nevertheless, it is abundantly clear that there are innumerable facets to the exciting and still emerging field of thin-film technology. It needs to be emphasised that significant achievements in the science and technology of thin films are only possible if the facilities and scientific skills of personnel in such diverse areas as vacuum technology, surface analytical technology, surface science, solid state electronics, and solid state physics are brought together. Unfortunately, this demands a very expensive and sophisticated laboratory manned by good broad-based scientist-cum-technologists. It is my view that although nuclei of thin-film laboratories have mushroomed in almost all our educational institutions and national laboratories, most, if not all, are subcritical and don't appear to promise any worthwhile advance in this area with their existing facilities.

A Senior Professor of Solid State Physics, and Dean of Post-Graduate Studies and Research at IIT, Delhi, K. L. Chopra has held senior R & D positions in Canada, West Germany and USA. He has established a school of Thin Film Physics and Technology at Delhi which has developed over a dozen processes/devices some of which are currently under production in smallscale industries in India. Prof. Chopra was recently awarded the S. S. Bhatnagar Prize in Physical Sciences for 1975.

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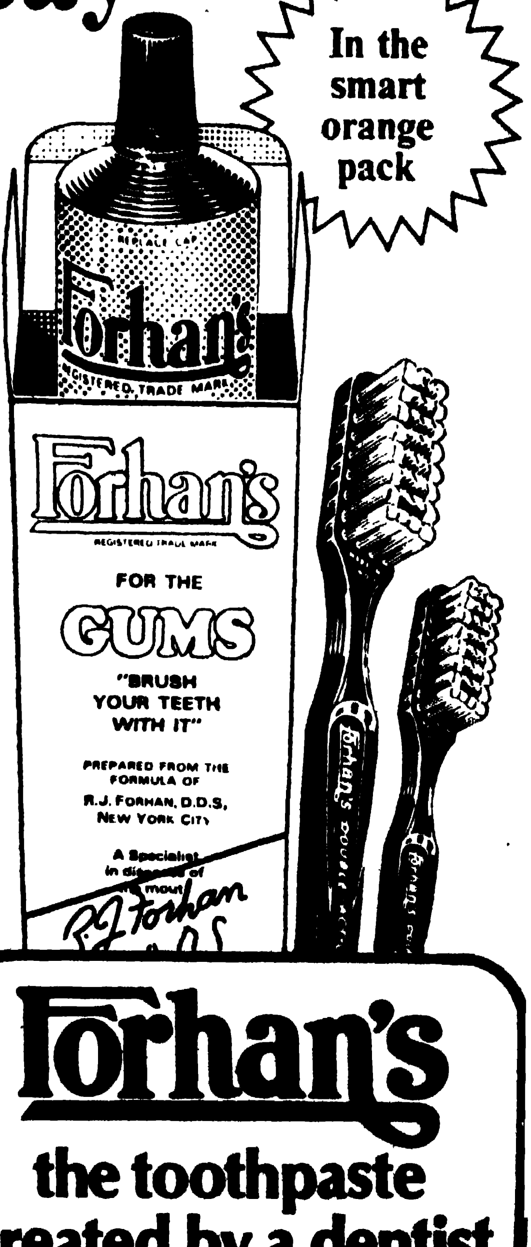

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NUCLEAR DATING

Nondestructive Dating of Glass Objects

A method of dating or authenticating man-made glass objects has been proposed by Dr. W. A. Lanford of the Department of Physics, Yale University, New Haven, Connecticut, USA, in an article in *Science* (**196,** 975, 27 May 1977). The report, in fact, includes only some preliminary tests he has conducted as an exploration of the potential of the method.

The dating of glass objects, no doubt, has an historical value since glass has been used for thousands of years. Glasses are unstable with respect to reactions with water. On exposure to atmospheric water, the surface of glass begins to hydrate. Glass is primarily a three-dimensional matrix of silicon and oxygen atoms, and it is the Si-O-Si chain which reacts with water to form the hydrate. The rate of hydration depends on the rate of diffusion of water into the glass, which is extremely slow. The relation between the thickness of the hydration layer, X, and the age of the sample, T, is given by $X^2 = KT$, where K is a constant. K would depend on the composition of the material, the method of manufacture and the environment in which the sample remains.

Obsidian, a natural volcanic glass that was used by ancient man to make arrowheads, knives and other tools, also hydrates like ordinary glass, but with a difference. Since hydrated obsidian has a specific volume different from unhydrated obsidian, unlike man-made glass objects, there is a stress line between the hydrated and unhydrated regions that appears as a dark line on illuminating the sample with polarised light. But optical measurements on obsidian require cutting, mounting and polishing a thin cross-section of the surface. Art historians, understandably, would not like their objects to be destroyed.

The proposed method of Dr. Lanford is based on a resonant nuclear reaction between nitrogen-15 and hydrogen, yielding a characteristic gamma ray. The yield is proportional to the hydrogen concentration at the surface. At energies above or below this resonance energy, the yield from the reaction is negligible. But, as the energy of nitrogen-15 is raised, it loses energy on passing through the sample, and the resonance energy is again reached at some depth. The yield of gamma rays is then proportional to the concentration of hydrogen at this depth. Hence, by measuring the yield of characteristic gamma rays versus the energy of nitrogen-15, one can determine the concentration of nitrogen as a function of depth. In his experiments, the sample was bombarded with nitrogen-15 from an accelerator.

Dr. Lanford with his technique has measured the hydration thickness of American glasses of known ages (less than 200 years old) and shown that qualitatively the relation between age and hydration thickness holds true. He contends that a detailed study of the composition dependence of K may make it possible to develop a quantitative dating procedure. According to him, his method will prove most useful in authenticating glass objects.

The results are preliminary in that he has shown the potential of the method only in some recently produced glass, but, he claims, there is no reason why the method cannot be applied to ancient glasses. However, one pitfall is that the surface corrosion present on excavated glasses may make reliable hydration dating difficult. Adding a futuristic note, he says that the glazes on pottery are chemically similar to glass, and it may be possible that a dating method for glazed pottery based on the resonance technique can be developed.

ORNITHOLOGY

Do Birds Navigate Using Magnetic Fields?

How birds navigate continues to be a topic of investigation and discussion. Various methods have been suggested—the Pole Star, the Sun compass, sense of smell, magnetic fields, etc. Some support to the contention that birds navigate by using the earth's magnetic field has been provided by Dr. F. R. Moore, a zoologist at the Clemson University, South Carolina, USA. The novelty of his investigation is that he has used direct visual observations on free-flying birds, whereas most of the evidence that birds extract directional information from the geomagnetic field has come primarily from controlled cage experiments with passerines and non-passerines and from homing experiments with pigeons. The details of his study are reported in *Science* (**196,** 682, 6 May 1977).

He has used data on passerine birds collected by S. A. Gauthreaux, Jr., during the spring and fall of the years 1968 through 1974 in the south-eastern United States. The latter had devised a technique called the ceilometer watch where the direction of movement and number of migrants passing through vertically directed beams of light are noted. Moreover, Dr. Moore has analysed the influence of magnetic fields on birds that migrate at night when magnetism might be more important (previous studies have found a relation between the flight direction of day-time migrants and geomagnetic disturbances, but the results have been questioned, since during the day the Sun compass dominates).

Dr. Moore had compared the migrating birds' orientation with the short-term fluctuations of the earth's magnetic field. He found that the more intense the geomagnetic disturbance, the greater is the spread or variation in the birds' paths. In the spring, the vertical component of the magnetic field was found to be the important variable. In the fall, the horizontal component was the important variable. Fluctuations in the declination of the magnetic field were found to have no effect, regardless of the season.

Dr. Moore claims that he has demonstrated a strong correlation between the orientation of the free-flying nocturnal migrant birds and geomagnetism, but whether the magnetic disturbances act directly or indirectly on the birds' orientation system is not clear. In any case, nobody, Moore included, knows how birds can sense magnetic fields. Hence, he concludes that though the results indicate that geomagnetic disturbances influence the orientation of free-flying migrants, the evidence is not sufficient to show that geomagnetism is a cue in their orientation system.

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GEOPHYSICS

Artificial Pulsating Auroras

Auroras, popularly known as the ' northern lights ', not only fascinate observers but continue to be objects of intense investigation by geophysicists. They are known to be produced when electrons precipitated from the radiation belts interact with the atoms in the upper atmosphere. But, they come in a variety of forms and very little is known of the detailed mechanisms by which such forms are produced.

Drs. C. Deehr and G. Romick of the Geophysical Institute, University of Alaska, Fairbanks, Alaska, USA, have now produced what are called pulsating auroras by releasing barium vapour into the upper atmosphere (*Nature*, **267**, 135, 12 May 1977). These are rare phenomena consisting of irregularly shaped patches of light some 10 to 50 km in extent that appear to turn on and off regularly with a period of the order of 10 seconds. They had previously been observed predominantly at altitudes below 100 km. High energy electrons, between 10 keV and 60 keV are usually involved.

The electrons causing the auroral displays would, no doubt, be affected by electric and magnetic fields and by the wind in the upper atmosphere. The Alaskan scientists were, in fact, measuring the conventional parameters in an aurora in the polar regions, when they discovered the completely unexpected pulsating aurora. The technique was to fire a rocket to an altitude of 250 km (F region of the ionosphere) and then explosively release from a canister a cloud of barium vapour. Sunlight interacts with the cloud to ionise it partially, to form a cloud of ions which resonantly scatters purple light from the Sun, and a neutral cloud which scatters green light. The neutral cloud is blown across the sky by winds while the ionised cloud is driven by the combination of electric fields and winds. Tracking both clouds optically from the ground provides information of the winds and electric fields at an altitude. The barium release technique is being used at Thumba, Kerala, to study the upper atmospheric conditions over India.

The unexpected finding of the Alaskan scientists is that when the cloud was released above the diffuse glow of a natural aurora, it induced pulsating auroral displays beneath the cloud. The release reported by them is the only one to take place within a significant amount of natural aurora and its presence seems to be a necessary condition for the pulsations. The artificial pulsations were found in one of the natural auroral spectral lines at 200 km altitude, where electrons of 500 eV deposit most of their energy.

The importance of their findings is that it may now be possible to generate pulsating auroras artificially, so that the mechanism of their production can be studied in detail. The speculation is that the beam of electrons is modulated by some plasma wave on its way down the magnetic field lines from the outer radiation belt.

MEDICINE

Is Cowpox Caused by Cows ?

Cows need not be the natural reservoir of cowpox. This is the major conclusion of a review of 10 confirmed human cases of cowpox made by Dr. Derrick Baxby of the Department of Medical Microbiology, Liverpool University, Liverpool, UK. The details of his study are reported in the *British Medical Journal* (**1,** 1379, 28 May 1977).

Cowpox has been traditionally regarded as an occupational disease of dairy farm workers. Most workers assume that the cow is the natural host and reservoir of cowpox virus, although the possibility of some unknown wild animal or bird being the host has been raised. There have also been reports of isolated cases of human cowpox in which contact with cattle was not established.

Dr. Baxby has reviewed 12 separate cases of confirmed cowpox infection (10 of them in man) occurring in 1965-76 in an attempt to provide information on the natural history of the disease. There was no connection between them, and they occurred in different places at different times. Six of the patients including three children had severe infections and five were admitted to hospital. In five cases, cows were found infected and in three, farm workers were also infected. In three cases, both men and cows were infected, but how the latter acquired cowpox could not be determined. In seven of the human infections, enquiries failed to establish direct contact with cattle, although all of them had lived in or visited rural areas. Clinical and serological examination failed to show evidence of cowpox in the cattle. Indirect infection from cattle was, therefore, unlikely and, in addition, none of the patients had been away from home, at the time the infection occurred.

The Liverpool microbiologist states that his observations, together with other information about infections known to be enzootic in cattle, lead to the suggestion that cows are not the natural reservoir of cowpox. It is possible that both cows and humans become infected accidentally - cows from the reservoir and man either from the cows or the reservoir. According to him, the reservoir could be some small wild mammal. He, therefore, advocates that the role of small wild animals as hosts and vectors of " cowpox " should be investigated.

Another interesting point, not concerned with Dr. Baxby's work, is that the World Health Organisation has recently claimed that it has wiped out small pox from India and many other countries of the world. But some workers suspect that the small pox virus may also be carried by animals, though at present latent, and the infection may appear again in humans.

K. A. NEELAKANTAN

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CUT & POST TODAY

on scientific breeding of goats

R. R. MISHRA

The goat is a multipurpose animal. It yields milk, meat, skin, mohair and pashmina. Goats are closely related to the sheep and the domesticated varieties are widely distributed throughout the world. Seventy per cent of the global goat population of 383 million resides between latitudes 30° north and south. India alone possesses about one-fourth of this (68 million). The goat population of India accounts for more than half of that in some representative countries of the tropics and subtropics (Table I). The goat is often spoken of in our country as the " poor man's cow ", and it has probably assumed an added importance because of its association with Mahatma Gandhi.

Docile in nature and cleaner in habits than cows and buffaloes, goats are quite popular as milch animals in Switzerland, France, England and the USA. But, we have only eight to ten million goats which can be considered suitable for milk production; their annual milk yield is less than one million tonnes. In India, goats with one to five kg of milk yield per day are rare, but there is no reason why such goats cannot be produced in millions with proper scientific breeding.

Apart from the milk they yield, other advantages of goat breeding and husbandry are the meat obtained from male kids and old does as well as the costly hair (mohair, pashmina) from their body coat. Goat meat (chevon) is highly preferred, since its fat is mostly concentrated near the viscera and the meat is less marbled than that of other animals. The demand for goat meat in India, at present, exceeds the supply. Goat skin (leather) and blood albumin are other products gaining popularity.

Goat's milk is especially valuable since it resembles human milk more closely than does the cow's, the sheep's or the buffalo's (Table 2). One important characteristic is that the casein in it, during digestion, forms a less tough and more friable coagulin than does the casein in cow's milk, so that digestive proteolytic enzymes penetrate and break it down more rapidly. The other characteristic is the smaller fat globules, which make it easy to digest and, hence, important in the nutrition of infants, invalids and convalescents, especially those suffering from chronic diseases and digestive upsets, or who are allergic to cow's milk. Its curd and other products are also easily digestible. Again, the bacterial count of hygienically produced goat milk is lower than that of milk from other species. This is why Hippocrates, " the father of medicine ", is said to have advised its use during many human ailments.

A healthy goat yields one-fifth of her body weight per day as milk, or 10 to 15 times her weight in a lactation period of 200 to 250 days. A dairy goat, in fact, may be considered as a hygienically stored milk-pot, as it can be trained to let down milk any time of the day. However, two to three milkings a day in regular hours is advised. Goats are at their prime at four to six years of age, but can continue to give a good quantity of milk until they are nearly 12 years old. Normally, a goat

Table 1: [illegible] the importance of goats as compared to cattle and sheep in [illegible] countries of tropics and subtropics (FAO, 1970)

Country	Population in thousands			Ratio between species		
	Goat	Sheep	Cattle	Goat	Sheep	Cattle
India	68,000	42,300	176,400	1	0·6	2·6
Indonesia	7,000	3,700	[illegible]	1	0·5	1·0
Iraq	2,[illegible]	[illegible]	[illegible]	1	[illegible]	0·8
Jamaica	[illegible]	[illegible]	[illegible]	1	0·8	0·7
Mexico	[illegible]	[illegible]	[illegible]	1	0·6	3·0
Nigeria	[illegible]	8,100	[illegible]	1	0·3	0·5
Turkey	18,463	36,471	12,7[illegible]	1	[illegible]	0·7

Table 2: Comparison of goat, cow, buffalo, sheep and human milk

Milk animal	Milk contents (%)				
	Water	Fat	Lactose sugar	Protein	Ash
Goat	[illegible]	4·87	4·[illegible]	3·7[illegible]	0·85
Cow	[illegible]	[illegible]	4·94	3·3[illegible]	0·74
Buffalo	[illegible]	[illegible]	4·92	4·37	0·94
Sheep	[illegible]	[illegible]	4·[illegible]	5·18	0·93
Human	[illegible]	[illegible]	[illegible]	[illegible]	0·30

reaches her highest yield in her second or third lactation, and she attains her peak yield in about 45 days after kidding. On the whole, the cost of production of goat milk is lower than either the cow's or the buffalo's milk.

One common complaint, however, about goat's milk is its peculiar smell. But this can be easily overcome by hygienic milking, straining and cooling of the milk. Destroying the musk gland and keeping the buck away also alleviates the bad odour. In any case, a consumer, selected at random and offered the choice of hygienically produced unlabelled samples of goat's milk and cow's milk, can seldom distinguish one from the other and may even choose the goat's milk.

Scientific management

The economics of goat-keeping, however, depends a great deal on scientific management. It involves proper breeding, proper feeding, proper housing as also looking after the herd-health, care of the young, care of the common ailments and diseases, cleanliness, etc, and a hygienic milking procedure. The best management, no doubt, is one which leads to higher production and economic out-turn.

Goats, so far, had developed through genetic isolation and natural selection. Their purposeful breeding, based on such selection factors as their general longevity and production capabilities, is a somewhat recent phenomenon. What a pedigree breeder needs most is a knowledge of both genetics and the various desirable strains he could make his choice from. His first consideration, evidently, will be the vitality and good health enjoyed, generally, by a breed. The second will be a stock's known capacity for milk production — its inherent milking capacity, feed-intake capacity and feed-to-milk conversion efficiency. A well-chosen breeding male can, indeed, influence a whole range of succeeding generations.

Once the breeding males have been selected, they are kept separately from the age of four months. A young female goat is first mated when she is about six months old, provided she has gained weight. A mother goat may come into heat again a month or two after kidding, when she could be mated again. A female, thus, can be made to kid twice a year.

The task of evolving new breeds by crossing local does with exotic bucks suitable for different agro-climatic conditions of India has been taken up under the All India Coordinated Research Project on Goats for milk, meat, mohair and pashmina. The prominent breeds of milch goats in the world are the Saanen, the Alpine, the Toggenburg and the Anglo-Nubian (see box on p. 27). And of the 21 goat varieties of India, the principal dairy breeds are: Jamunapari, Beetal, Barbari, Surti, Marwari and Osmanabadi. The present plan is to produce contemporary pure-bred locals and cross-breds with one or two exotic breeds (Alpine, Angora, Saanen, Predonskaya) depending on the location and the requirement.

Feeds and feeding

The goat is a ruminant, but its feeding habits are unlike those of sheep and cows. For its size, a goat consumes substantially more feed than either a cow or sheep, namely, 6·5 to 11 per cent of its body weight in dry matter, compared to 2·5 to 5 per cent in the case of cattle and sheep. Goats can satisfy their maintenance and production requirement on good fodder and pasture. It is interesting to note that a 45-kg body-weight goat requires 1·5 times as much feed per day for maintenance as would a cow of equivalent weight. For every 63 kg of feed consisting of common concentrates mixture, a goat has been shown to produce a decalitre more milk than a cow. As a rule, the goat should not be fed more than 50 per cent of dry matter as concentrates. The remainder of the ration should be roughages. (The leaves and stalks of plants rich in crude fibre form roughages, while grains and its by-products containing less crude fibre are concentrates.)

The roughages should be supplied in the form of hay, silages or roots (carrot). Good quality proteinous legumes like lucerne (alfalfa) or berseem hay is more desirable for milking animals. A proper concentrate mixture essential for the milking doe is composed mainly of cereal grains, including maize, oats and barely. However, to supply a properly balanced ration, these cereals have to be supplemented with protein-rich

Table 3: Apparent digestibility of various dietary constituents by goat, sheep, cattle and buffaloes on same diet (grass + groundnut cake, fed at 5 per cent of metabolic live weight)

Feed constituents	Goat	Sheep	Cattle	Buffalo
Dry matter	[illegible]·7	[illegible]	63·6	54·1
Organic matter	[illegible]	[illegible]	66·4	[illegible]
Crude protein	[illegible]·4	[illegible]	48·5	47·5
Ether extract	71·3	73·4	62·[illegible]	74·1
Crude fibre	[illegible]	[illegible]	61·[illegible]	[illegible]
Nitrogen-free extract	[illegible]	[illegible]·2	52·[illegible]	[illegible]

concentrates (vegetable oil cakes), minerals and, occasionally, vitamins.

Goats prefer coarse feed—cracked, coarsely-grounded grain. It is advisable to keep a block of trace mineral salt available all the time. As goats enjoy and need plenty of fresh water, they should not be allowed to drink from pools of stagnant water.

Housing

Proper housing for them is also equally important. They may be kept under wide shady trees, where available. But, it is preferable to house them in a shed or small barn which is also well-lighted and well-ventilated. The shed must be clean, dry and free from draughts. Dampness is dangerous as goats easily catch cold which may later develop into pneumonia (one of the few diseases to which goats are quite susceptible). Cheap houses with low roofs and large corral, hanging hay tracks, water buckets, concentrate trays, kid boxes and raised platforms with narrow drains are pre-requisites for the proper care of the milking does. The ideal width of the shed is 3 m to

A Barbari buck

DAIRY BREEDS

The Saanen breed is the milk queen of the goat world and has its home tract in Switzerland. Its coat colour is white, but sometimes it is cream or grey, particularly fawn at the spine. They do not as a rule carry wattles or tassels. The world lactation record in goats (305 days) is held by a Saanen goat in Australia, with a yield of 3,084 kg milk (3·3 per cent fat). A mature doe and a buck weigh 50 kg and 70 kg, respectively. Udders are usually shapely and well hung. The daily average yield of milk is 3 kg with an average lactation yield of 847 kg in 250 days.

The coat colour of the Alpine breed varies from black and fawn to white. The breed includes mainly heavy milkers (over 1,000 kg in 240 days), but butter fat and body weight average the same as with the other breeds of goats. The daily average yield of milk is 2·5 kg with an average lactation yield of 575 kg in 247 days. A doe weighs 50 to 60 kg and a buck 65 to 80 kg.

The Toggenburg breed originated in the valley of Toggenburg in Switzerland. Its coat colour varies from deep chocolate to pale-drab with light fawn or white markings down each side of the face and from the knees or hocks to the feet, around tails, rump and thighs. The ears are small and pricked. Two wattles or tassels are present at each side of the under parts of the neck. They are usually hornless, and the members of the breed are not very good milkers. Their average milk yield is 2 kg with 3·4 per cent butter fat. The lactation yield is 800 kg in 200 days. Kids at birth weigh 3 kg, the mature does, 45 kg, and bucks, 60 kg. This breed is better suited for adaptation in India.

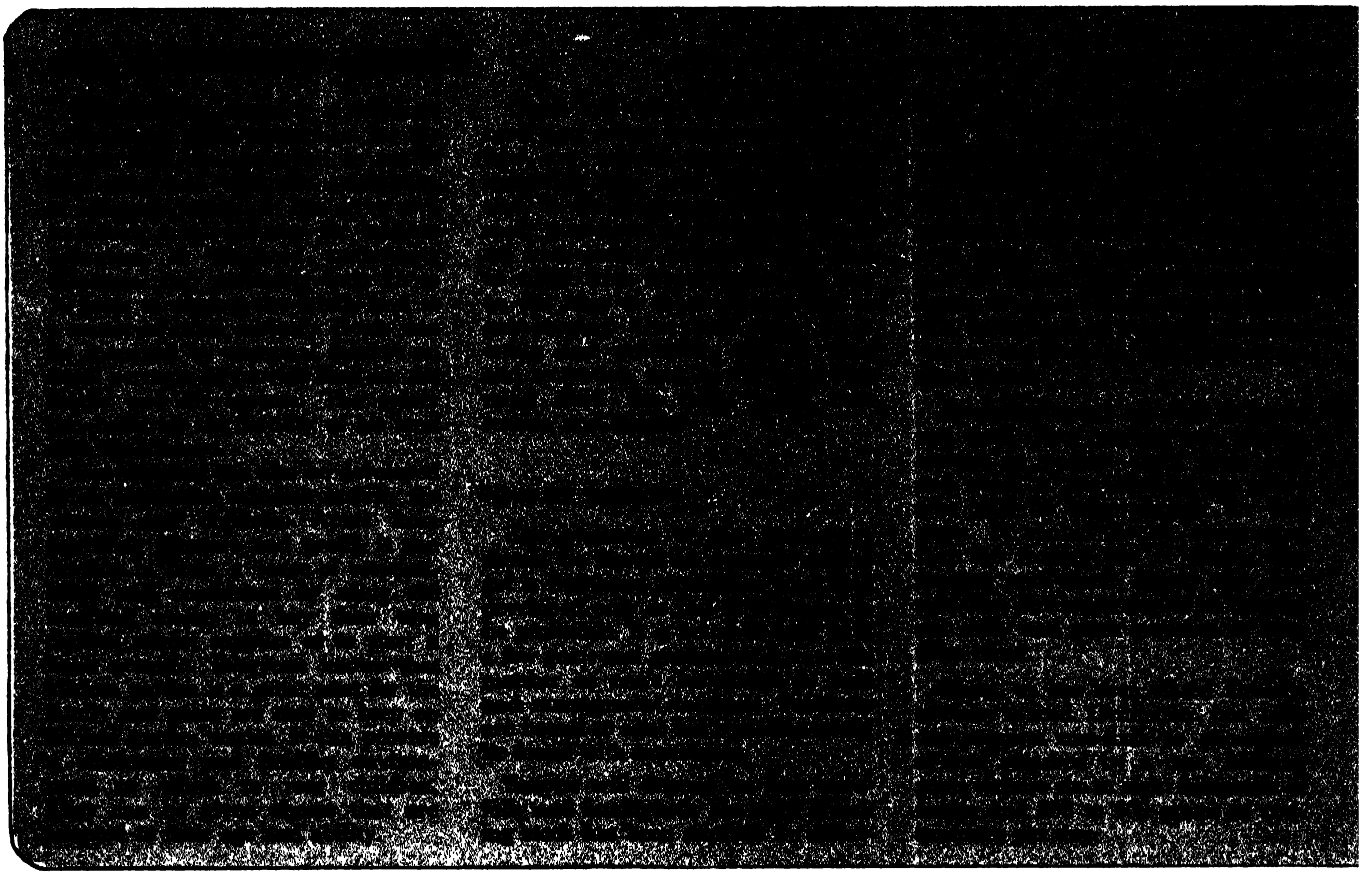
The Anglo-Nubian breed has resulted from the product of crosses involving Egyptian (Zariby), Indian (Jamunapari), Swiss (Toggenburg) and the old English-type goats. The Anglo-Nubian may be of any colour varying from the solid white to beautiful, marbled and spotted specimens in hues of fawn, black and grey. Big animals, they are consistent milkers with milk containing 5 per cent fat and 10 to 11 per cent solids-not-fat, and are usually called the "Jersey" of the goat world. On an average, they yield one kg milk per day. The lactation yield is about 300 kg in 300 days. The mature females weigh 40 kg and males around 60 kg. Milk from the Nubian breed is claimed to be cheap and best in quality.

Indian breeds

The Jamunapari is common near Etawah and Agra districts in western Uttar Pradesh. The coat colour is white with chestnut or light brown neck and face. However, goats with patches of tan or black are not uncommon. They are tall and leggy, with large folded, pendulous ears and convex face. The average weight of a mature female is 50 kg and that of a male 80 kg. The average milk yield is one kg per day with a lactation average of 196 to 272 kg in 210 to 283 days. The maximum yield reported is 4·85 kg per day and 544 kg in 250 days.

The Beetal belongs to the Punjab. They are large-sized goats with black and sometimes red coat colour, many with heavy white spots on the body. The eyes are black/blue with white or brownish corneal surroundings. The ears are large and hanging downwards. The face is convex. The wattles or tassels are generally present in pairs. Bucks mostly carry a tuft of hair under the chin known as beard. A mature female weighs 45 to 50 kg and a male 56 to 80 kg. The average yield of milk is one kg per day with a lactation yield of 107 to 288 kg in 160 to 244 days.

The Barbari is called the dwarf milch goat of India, mostly found near Agra, Mathura, Etah and Aligarh districts of Uttar Pradesh. They have very fine white fawn coat of short and silky hair. The ears are slender, rather small and stand erect from the head. The facial line is almost straight. The legs are short with strong and fine bones. The outstanding quality of the breed is its habit of stall feeding, which makes it most suitable for towns, where grazing facilities are lacking. The mature females weigh 25 to 30 kg and the males 35 to 45 kg. The average milk yield is 0·7 kg with a lactation yield of 101 to 228 kg in 210 to 252 days. They are considered prolific breeders, kidding twice in 12-15 months' time. **R.R.M.**



3·6 m, with a manger, 38 cm wide, running through the centre. Goats are tied on either side and about a square metre of space should be allotted to each goat. The milch goats, specially, should not be allowed to run together in their pens for getting roughages and concentrates. They are preferably fed in separate stalls or in a group of 8 to 10 does. It is better to house them in groups of 30 to 40.

Protection from common diseases forms another important area of scientific management. The following ailments are quite frequent among goats: pneumonia, tympany (acute form of indigestion), entero-toxaemia, acetonaemia, pregnancy toxaemia, eye

A Jamunapari buck at a livestock fair at New Delhi

Centres of research in goat breeding in India

For milk:

(1) National Dairy Research Institute, Karnal (Haryana)

(2) Kerala Agricultural University, Trichur (Kerala)

(3) Assam Agricultural University, Khanapara (Assam)
(Started for developing milch goats in 1971, has changed to developing meat goats in 1976.)

For pashmina and mohair:

(1) Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra)

(2) Indian Veterinary Research Institute, Mukteswar (UP)

(3) Leh Unit, Ladakh (J & K)

For meat [chevon]:

(1) Rajendra Agricultural University, Chotanagpur Centre (Bihar)

(2) R.B.S. College, Agra, UP

(3) Central Sheep and Wool Research Institute, Avikanagar (Rajasthan)

[illegible]

A flock of goats at NDRI, Karnal

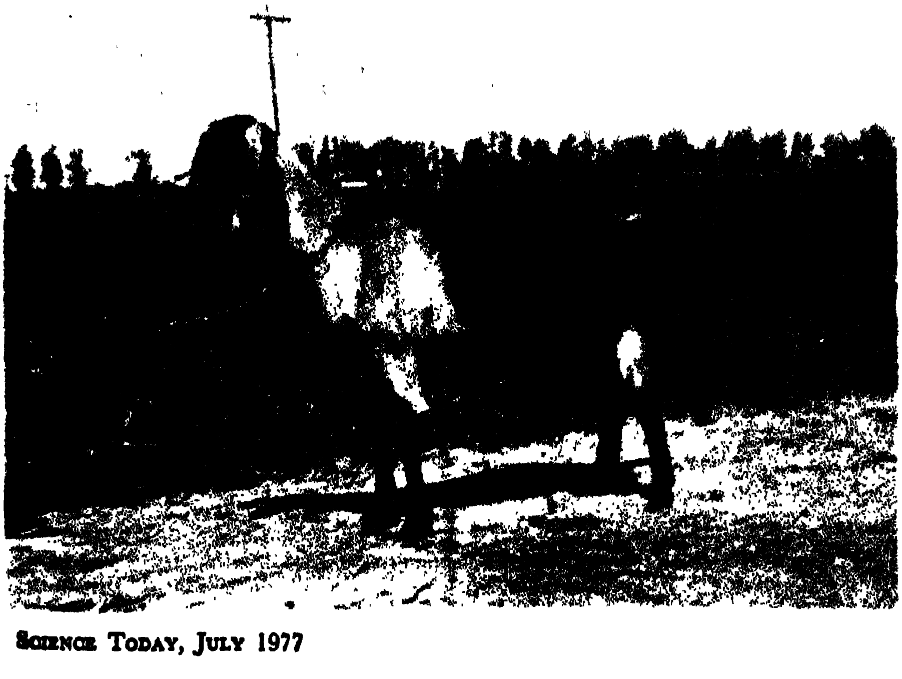
troubles, worms (tape worm, round worm, lung worm, ring worm, etc), diarrhoea, constipation, caked udder, lice, foot-and-mouth rot and sore teat, leading to blood in milk, and mastitis. Prophylactic measures include routine vaccination of kids at three months of age, and routine deworming at three-month intervals — preferably before and after the monsoon season. Periodical test of the flock against tuberculosis, brucellosis and parasitic worms are recommended. Caked udder or mastitis should be treated by fomentation with Epsom salt solution followed by application of Iodex or lard. Foot-and-mouth rot comes mostly in the rainy season. Soaking the affected area with saturated solution of copper sulphate and application of pine tar promotes healing after infection has been controlled.

Good care and management can prevent many of these diseases. Goats like to eat clean food and stay in clean, well-ventilated quarters; they also like to have an occasional bath in warm sunny weather. Cleanliness is the first principle of good health and goats co-operate fully in this endeavour. It is necessary to keep a sick goat warm and free from draughts by separating it from the healthy stock. A warm bran gruel may stimulate appetite under sick or debilitating conditions.

Goats are intelligent animals. They readily adapt to a particular environment, or a system of feeding or management, but they are also sufficiently mischievous to take advantage of any carelessness on the part of their owner. Mostly mismanagement, and not an inherent fault, is the cause of their alleged destructive habits.

Goat breeding and husbandry are, in fact, ideally suited to our rural economy. Dairy goats not only fit easily into the environment and socio-economic conditions that may be quite unsuitable for dairy cattle or buffaloes, but by regulating their breeding, they can also be made to yield sufficient milk for an average family of four to five members. It is possible to keep two goats for about one-fourth the cost of keeping a cow. They are of small size and have inquisitive feeding habits. They feed on leaves, kitchen waste, vegetable offals and graze on nearby fences. They have a high digestive efficiency for cellulose, high efficiency of feed utilisation, high fertility, prolificacy and short gestation interval. On an average, a goat will produce five daughters in eight years, while most cows and buffaloes are not able to produce five daughters in their lifetime.

An Alpine x Beetal cross-bred doe evolved at NDRI



Dr. R. R. Mishra is a senior scientist at D. C. G. Division, National Dairy Research Institute (ICAR), Karnal. His fields of specialisation are animal genetics, breeding and production.

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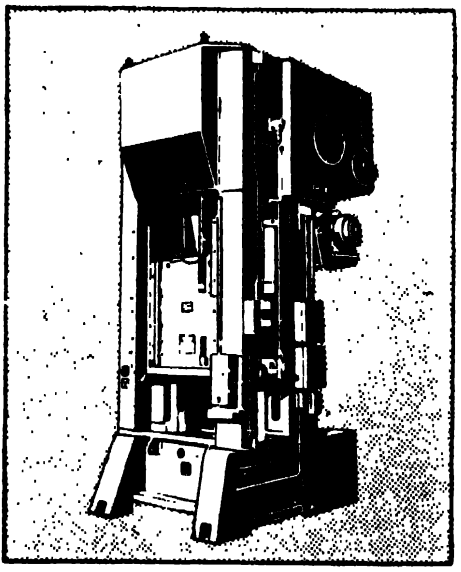

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LET'S GET TO KNOW OUR TREES!

Village Trees

It's an ancient tie that binds village life in India to the trees — be they in planted groves, on the borders of cultivated land or on forest fringes. Trees surrounded hermitages and were well cared for and preserved. In fact, the antiquity of some of our trees can be traced to references in folklores and legends, in tribal songs and in our immortal epics, poems and plays.

Tribal populations in many regions of our land have looked upon trees with a certain respect and, in some instances, fear, believing them to be the abodes of good spirits or evil. This may, perhaps, account for why some trees near villages have been allowed to survive when large tracts of forest flora have been devastated and laid bare to make way for new settlements and cultivated land.

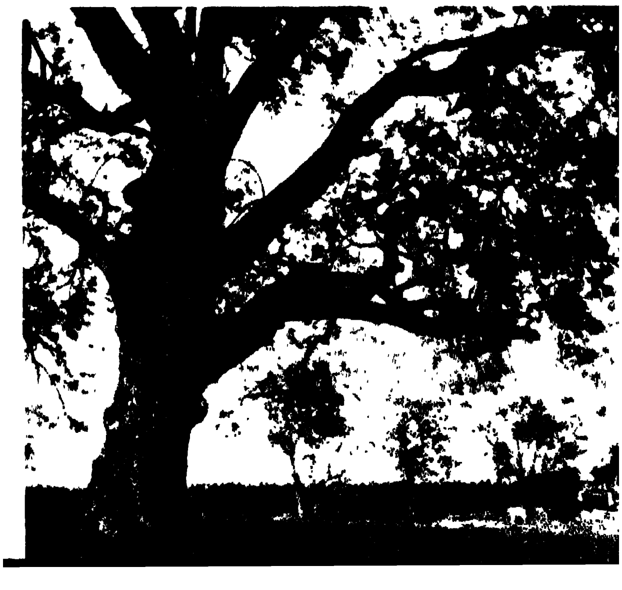
A very common but beautiful tree seen throughout India (from the sub-Himalayan tracts to Kerala) is the **tamarind** (*Tamarindus indica*). The tamarind is originally a native of the Sudanic region of tropical Africa; the period of its introduction into India is not known with certainty, though it is thought to be quite far back in time. (Some authorities believe that it is also indigenous to South India.) Its nativity notwithstanding, the tamarind has come to be recognised as an Indian tree, so much so that its common as well as scientific name is derived from the Persian "*tamar-i-Hind*" meaning "date of India".

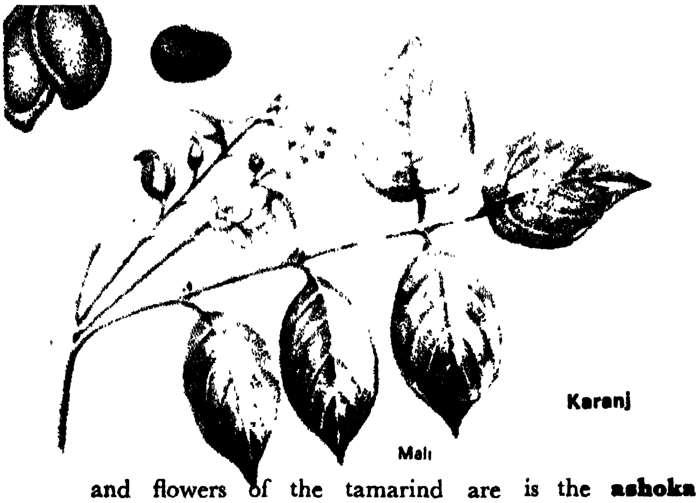
Though usually planted around villages, the tamarind has also run wild in some places because its seeds are dispersed in many ways including transport by water. It is often planted as a roadside or avenue tree. It has a thick greyish trunk with a girth of up to seven metres and may reach a height of about 25 metres. The crown, which is dense and many-branched, is composed of paripinnate leaves with 10 to 20 pairs of small leaflets. The tree is evergreen, but during the summer, there is an abundant leaf fall along with sprouting of new leaves in March and April. The small flowers appear in profusion between April and June but often go unnoticed being hidden by the leaves and often because of the great height. These little flowers reveal their remarkable beauty when freshly gathered and examined with a hand-lens: four creamy sepals, three unequal pale petals with a red filigree network of red veins, three green stamens and the single long pistil curving out of the centre.

The tamarind fruit is a pod about 10 to 20 cm long containing anything from three to 12 seeds. The seeds—dark brown in colour and each covered by a thick membranous envelop — are embedded in the red-brown fibrous pulp in the ripe pod. The pods, green when raw and covered with a rough buff coating ripen in the cold season. The tree is propagated from seeds, and in about 13 or 14 years starts to yield fruit and continues to do so for over 60 years. The long life of the tamarind tree is acknowledged in a tribal song of the Gonds of Central India where the singer laments, "The Tamarind I planted in my youth is full of life, but there is none in me". Some tribes in Maharashtra worship the tamarind as a totem (*devak*) and believe that sleeping under it is injurious to health.

Almost every part of the tamarind finds some use. The pulp of the ripe pod is sour in taste owing to the presence of tartaric, malic and citric acids, and is used as a souring agent for sauces and foods; the unripe pods make a fine tangy *chutney* when grated and blended. One variety of tamarind is also known where the pulp is acid sweet. The pulp, separated from the fibre, is often processed for culinary use, though the salted crude pulp is preferred by the majority. The pulp is also a purgative by virtue of its tartaric acid content. The Burmese make an excellent sherbet, called *phyaw-ye*, by mixing the pulp with gur (jaggery) and water and cooling it. And, then, every housewife knows that tamarind pulp is a good polish for copper and brassware.

The seed kernel, which contains 17 per cent protein, is sometimes ground and consumed by tribal folk. Tamarind kernel powder, known in commercial circles as TKP, is rich in a polysaccharide, jellose, which imparts a peculiar property to it which makes it useful in a variety of ways: the powder, when boiled and dried in layers, produces elastic sheets. This powder is, therefore, used for stabilising jams, jellies, icecreams, jujubes, cosmetics, printing pastes, etc. Huge consignments are exported to the West for this purpose. In fact, India is the largest producer of tamarind products. Tender leaves


The lowest branch of this neem tree at Shoigaon in Maharashtra is said to be sprouting *sweet* leaves since, legend says, the branch had hit the head of the Raja of Kadoba passing below



Karanj

and flowers of the tamarind are edible and used as vegetables. The heartwood is extremely strong and durable and is a prized timber for making durable implements.

Perhaps, one reason for the tamarind's durability is the fact that it is drought-resistant and can withstand the full blast of the monsoon as well. Its dual-root system comprising a superficial and a deep one allows the tree to survive under difficult conditions. The superficial roots, ramifying close to the topsoil, permit competition with grasses for nutrients from the soil, while the deep roots plunge deep down into the soil to tap ground water under drought conditions. Taken together, this means that such a root system prevents soil erosion. Dr. M. S. Randhawa recommends that tamarind trees along with other hardy trees, like the neem, should be planted on wastelands with degraded soil as a measure of conservation and as an exploitable resource.

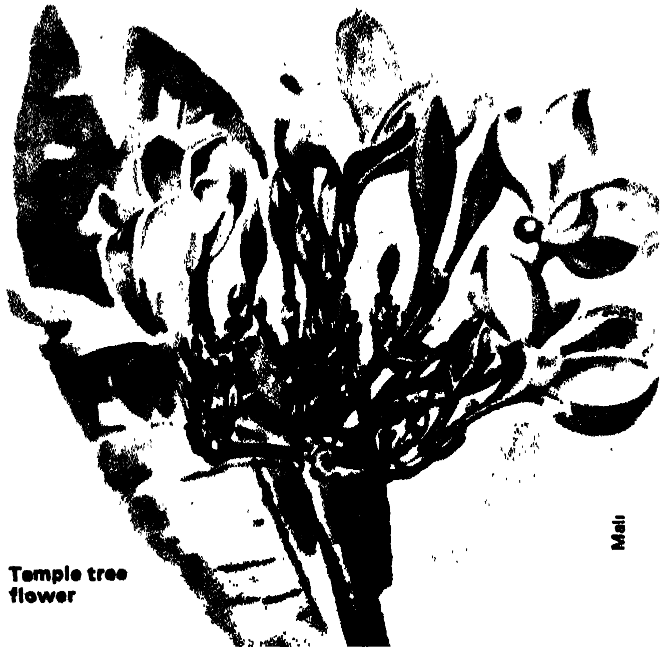
Java plum (Jamun)

A tree of singular beauty grown near temples — especially Buddhist places of worship — is the **ashoka** (*Saraca asoca*). The ashoka tree is a medium-sized evergreen tree, indigenous to India, Burma and Malaysia. It is found all over our country, both in the wild state and in cultivated groves called *vans*. (Each *van* may consist predominantly of one species of tree, in which case it is prefixed by the name of that particular tree, as for example, in this case, the grove would be called *ashokvan*.) Ashoka groves were carefully tended and maintained by ancient Buddhist monks who were inspired 20 centuries ago to carve works of art into living rock. The ashoka grows along streams and in evergreen forests of the west coast of India, the Khasi, Garo and Lushai hills, and also in the Andaman islands. The compact canopy of dark green leaves crown the trunk which has a smooth, dull grey or brown bark; in older trees, however, the bark becomes black, with a rough, warty surface.

The compound leaf is about 30 cm long and bears four to six pairs of long leaflets. By the end of the cold season new leaves emerge, light red to delicate mauve at first, but turning dark green as they mature. The drooping young leaves hanging like red silken tassels from the ends of branches present an unusual and interesting sight, particularly when back-lighted.

The ashoka flowers throughout the year in some locales, but January and February are the best months to witness its flowering glory. The fragrant flowers occur in dense clusters all over the tree, yellow to yellowish-orange at first, then changing colour to a bright vermilion. The corolla is tubular and opens out into four small lobes; the many long stamens that emerge from each tube give a hairy appearance to the flower cluster. The general aspect during flowering

Ashoka



Temple tree flower

s one of scores of fiery red embers glowing on the tree; probably, this spectacular flowering of the ashoka inspired and perpetuated the popular belief that the tree would flower only when kicked by the left foot of a pretty maiden (as Kalidasa has described in his play *Malavikagnimitram*)! The *Ramayana* describes the sojourn of Sita in an *ashokvan* after her abduction by Ravana. The tree has also been represented in sculpture: a bracket and railing pillar discovered at an ancient site at Kankali Tila near Mathura belonging to the reign of Kanishka depicts a woman under an ashoka tree (see p. 34). Buddhists venerate it because Gautama Buddha is believed to have been born under an ashoka tree.

The ashoka tree has been found to possess medicinal qualities: bark extracts, which contain a glycoside (the active principle), stimulate many tissues, notably the uterus. For this reason it is used in uterine disorders; in fact, the Indian Pharmaceutical Codex officially recognises two liquid preparations made from the ashoka.

Mali

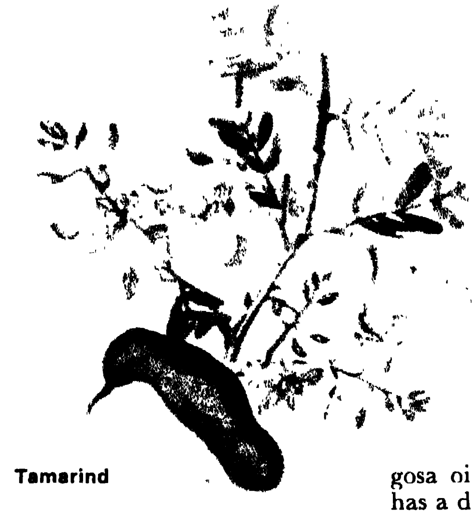
Neem

The long, flat, four to eight-seeded dark pods are chewed in Assam (instead of arecanuts); they are also fed to livestock. The wood of the ashoka is light, soft and reddish-brown, and is used for implements and building purposes.

Kilometre upon endless kilometre the dry plains of the Deccan plateau stretch out towards the horizon in a continuous monotony. As one travels from one village or town to the next, the regularity of the treeless cultivated fields of black cotton soil (where undoubtedly good forests flourished in bygone days) is broken, off and on, by patches of trees that have been spared the villagers' axe. A prominent tree in these sparse manifestations of verdure is the **neem** or **margosa** tree (*Azadirachta indica*).

Though familiar to the village folk and the interested urbanite, it can be easily overlooked as it lacks showy

green tree which may reach to a height of about 8 to 10 metres. In the drier regions, where it thrives well in the black cotton soil, it tends to be deciduous. The bark is thick and may be heavily fissured; it is dark grey on the outside and reddish on the inside. The leaves are very distinctive; each leaf is pinnate and has an odd number of leaflets. The leaflet, too, is characteristic – it has a serrated (toothed) margin and is curved with one half of the leaf larger than the other, giving the appearance of a scythe.



Tamarind

Flowers appear between March and May every year in large numbers, scores of which are borne on long slender stems arising from the axils (angles) of the leaves. Each flower has five sepals and five petals and bears one fruit. The flowers attract large gatherings of bees and other insects. The fruit is about two to three cm long, oblong, green when raw but yellow on ripening from June to August. The single seed it contains is surrounded by a very bitter pulp; in fact, all parts of the tree are bitter including the heartwood which resists attack by insects and termites.

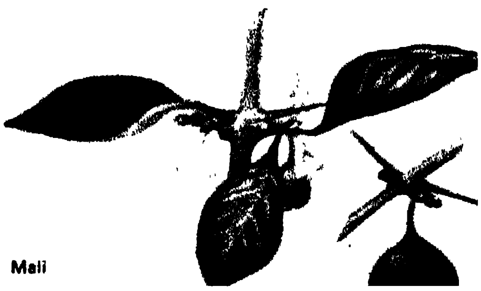
The tree figures in Indian folklore; some tribes of Maharashtra worship the neem tree, too, as a totem. Unlike the tamarind, the neem tree is considered health-giving. On the Hindu New Year's day, the bitter

Mohwa

leaves are eaten with sugar to ward off illness. The tree has also inspired some folk songs. An Avadhi song from North India glorifies the tree: in the opening stanza a daughter implores her father not to cut down the neem tree as it offers a roosting place for sparrows; this song is called *hindole-ka-geet* (song of the swing). A Kannada song from South India extols the neem's cool shade.

The leaves possess an insecticidal action, and dried leaves are kept with clothing, books, grains, etc to keep away insects. The pulp of the fruit, though bitter, is eaten by monkeys. The seed oil (margosa oil) is acrid, bitter, yellow and has a disagreeable odour. It is used in the indigenous system of medicine for treating skin diseases and rheumatism, and as a vermifuge. The bitter, active substance present in the plant is a chemical known as nimbidin. The oil has been used for manufacture of medicated soap. Twigs of the neem serve as rustic toothbrushes. The

Alu



Mali

reddish brown, termite-resistant heartwood is used for construction of houses, boats, ploughs, toys, etc, and is said to resemble mahogany in beauty and hardness. Incidentally, the Latin name of neem was adopted from *Azadirachta*, the Persian name of another tree (*Melia azaderach*) which superficially resembles the neem and belongs to the same family (Meliaceae).

An important tree yielding excellent edible fruit, good timber and medicinal ingredients is the well-known **jamun** (*Syzygium cuminii*). This evergreen tree which attains a moderate to large size is found throughout India in both the wild state and under cultivation in orchards. The jamun, also sometimes called the Java plum or black plum, when planted and tended has a straight trunk with greyish-brown rough bark, but in its natural habitat the tree becomes knotted and stunted, and is often festooned with mosses growing on its branches, especially in the wet rain forests. Sometimes it is planted on the roadside as an avenue tree or as a windbreak.

The leaves, about 9 to 10 cm long, are single and entire, arising on opposite sides of a central stem. They have a rather strong though not unpleasant aromatic odour when crushed. The flowers which bloom from March to May are small and occur in aggregations on stems below the leaves; thus, they may not be noticed by the casual observer. The whitish calyx and corolla are single and not divided as in other plants; the cup-like corolla falls off and exposes the numerous hair-like stamens — which just seem to burst out of the calyx.

Jamun tree

Woman under a tree: sculpture from the Kushan period (Mathura Museum)

Fruiting occurs from June to August and often a tree is heavy with the purplish-black, smooth-skinned, glossy fruits each of which may be two to four cm long and oblong with one seed embedded in purple-red pulp. The delicate fruits often fall off in a stiff wind and litter the ground, attracting blue-bottle flies, butterflies, and in forests, perhaps an occasional jackal or civet.

Several types of jamun are recognised by the different colours and sizes of the fruits. Two varieties usually encountered are: the big-sized *ra-jamun* with a small seed and sweet voluminous pulp, and the *katha* variety with small fruit and acidic pulp. The jamun grows well in widely differing localities but thrives where the soil is damp, like the banks of streams; the *ra-jamun* is particularly hardy and resists waterlogging. The jamun coppices well, that is, when the main trunk is felled, new shoots develop from the lower portion and grow to tree proportions. Propagation is by seeds and a tree starts yielding fruit in eight to 10 years and continues to do so for about 70 years. The leaves are fed on by caterpillars of numerous moth species; on some trees one may find the ingenious leaf nests of the large vicious red ants, *Oecophylla smaragdina*, much to the dismay of young boys who climb them for their fruits.

The jamun is mentioned in the works of Valmiki and Kalidasa; the Hindus consider the tree to have a sacred association with Lord Krishna.

Most parts of the jamun tree are useful. The fruit is edible though some individuals may not like its astringent taste. Some improved varieties have been developed which are seedless and more palatable. The pulp is rich in glucose and fructose and is made into preserves, squashes and even a liquor. The flowers are a source of honey, especially of the big rock bees (*Apis dorsata*) of the Western Ghats.

Despite the strong aroma, jamun leaves are a good source of protein (9 per cent) for livestock; they also serve as green manure, and as feed for the larvae of the *tussar* silk moth. The seeds are rich in protein and calcium and serve as feed for livestock.

In the Indian systems of medicine, the jamun has been used for treating diarrhoea, dysentery and diabetes. Recently, the dried alcoholic extract of jamun seeds has been found to reduce the blood sugar level of diabetic patients. Jamun timber is reddish-grey to brown in colour; being rather durable under water, it finds application in boat-building, fashioning oars and agricultural implements, tool handles and cart wheels.

The **mohwa** or **Indian butter tree** is a medium-to-large deciduous tree with large elliptical, entire leaves found all over the Indian plains and forests. It is known as *madhuka* in Sanskrit from which the botanical name *Madhuca indica* has been adapted. Between February and April, the leaves fall off and bunches of flowers appear at the ends of the spreading crown. Each flower, which is borne on a furry brown stalk, has a tubular, thick, white fleshy corolla which has a sickly sweet odour and taste. The generous yield

Mohwa tree

of its edible flowers is what makes the mohwa an economically important tree. Tribal folk have for centuries gathered and consumed its fleshy flowers which can also be dried and preserved. New leaves appear just about the time the tree flowers and are initially reddish-brown turning dark green later. The oval fruit is about five cm long, light brown in colour and usually contains one seed. The oil extracted from mohwa seeds has been used by tribals as a cooking oil. In cold weather, it solidifies to a buttery consistency and is sometimes used as an adulterant of ghee. The oil is also used for making laundry soap, candles, as a lubricant and a raw material for stearic acid. The oil acts as an emollient in skin diseases, and is also a laxative. The cake left over after extraction of the oil is unfit as an animal feed because it contains a toxic principle (saponin) called mowrin; it finds use however as a manure, and is applied to lawns and golf courses because of its insecticidal properties. In South India, the residue is employed as a hairwash mixed with the soapnut pulp. The dried flowers are rich in sugar, calcium and vitamins; they are eaten either raw or cooked, but vomiting and light-headedness may occur if a large quantity is consumed. A very strong and heady liquor can be prepared from the flowers. Some tribals worship the mohwa tree during marriage rites: the bride smears it with vermilion and embraces it.

The **karanj** or **pongam** (*Pongamia pinnata*) is a fairly large tree found growing throughout India along stream banks and tidal forests. This deciduous tree belongs to the pea family and is widely distributed in South-East Asia and even up to Australia; it is also popular as a roadside tree in some of our cities. Between February and April, the leaves are shed and new leaves grow; the tree then bursts into bloom and entire trees are seen to be decked with the small pale-pink or mauve flowers many of which fall off and carpet the ground below. The single-seeded flat pods develop in May and June, and in some places in November and December.

The karanj is a fast-growing tree which also coppices well. It is a host to the lac insect. The oil extracted from the seeds has a disagreeable odour and is used as an illuminant, for dressing leather, soap-making and as a lubricant. It has been used to treat skin diseases like scabies and leucoderma in indigenous medicine. The active substances present in the oil are two bitter flavones, karanjin and pongamol. The seed cake is not fit for livestock but is used in sugarcane fields and gardens as it repels red ants and is also good as manure. Local people make cordage from the stem bark, and feed the leaves to their domestic stock; an infusion of karanj leaves is a native lotion for cleansing sores and ulcers. For afforestation, especially of watersheds in the drier regions, the karanj has been recommended.

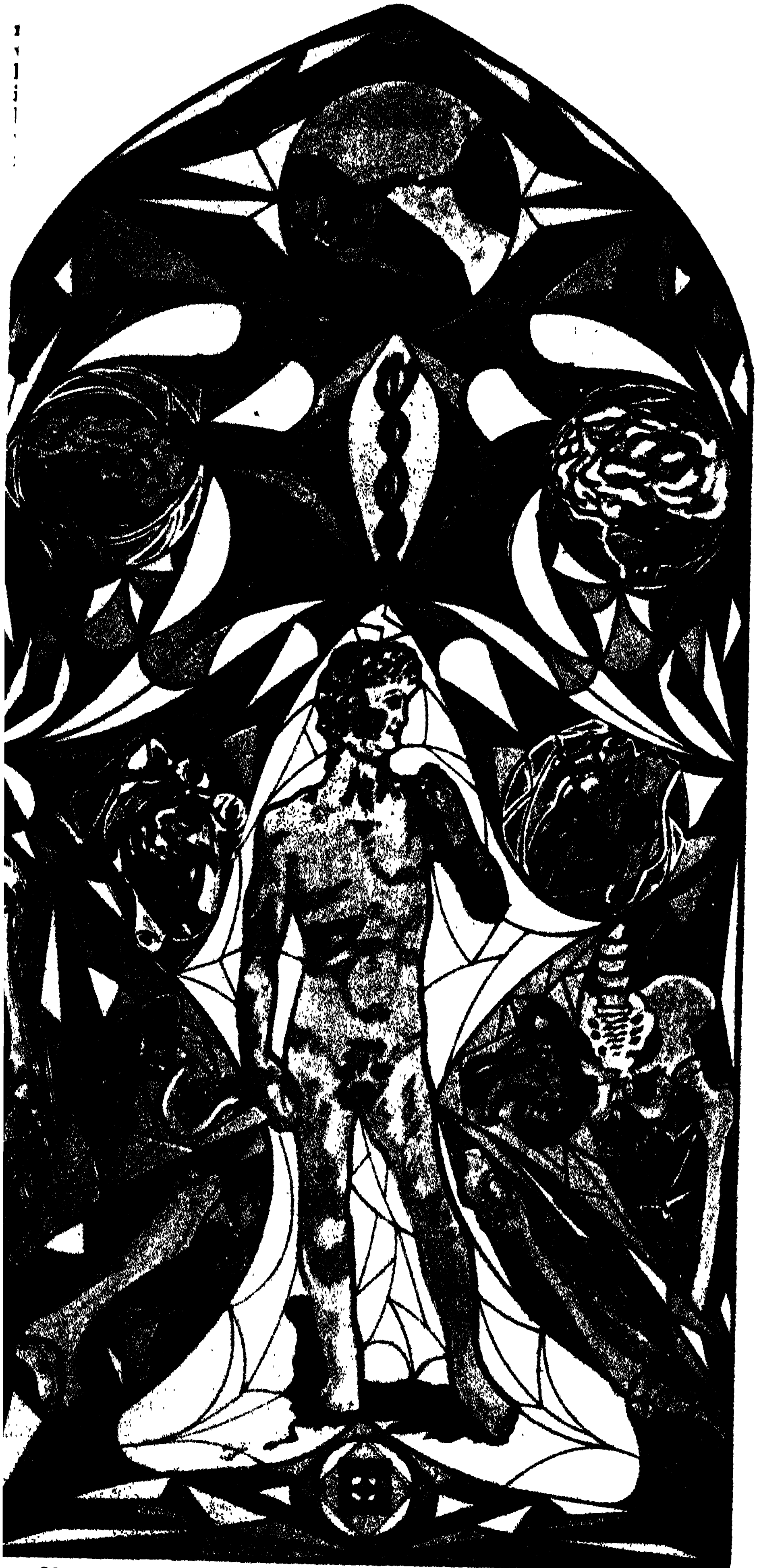
In 1841, a handsome flowering tree of the dogbane family (*Apocynaceae*) was introduced into India from the Philippines. This tree, variously known as the **pagoda tree, temple tree,** or **dead man's flower** is *Plumeria rubra* which is named in honour of the 17th century French botanist, Charles Plumier. It is a native of Mexico and Guatemala and like most exotics flourishes on our soil where it is planted near temples, over graves and generally in some gardens and parks. There are about eight species of *Plumeria* in India but there is some confusion concerning their nomenclature since there is a good deal of overlap of their features and some may in fact be hybrids. The tree flowers all the year round. The large, fragrant, white or pink flowers have five petals which are tinted with yellow at the base on the inside. A red form of the tree (the frangipani) is also sometimes grown. The leaves are long and narrow. All parts of the tree exude a milky latex; the Sanskrit name *kshira champa* (milky champa) refers to this characteristic. The latex has been used in native medicine as a counter-irritant in rheumatism, as a purgative and as an ointment for itches and bleeding gums. The flowers are threaded together to make garlands, and in some places the leaves are tied to the trunks of coconut palms to protect them from infestation by the long-horned beetle. The pagoda tree is very popular for its sweet-smelling flowers and the ease with which it can be grown from cuttings.

A rather unusual tree for a townsman, who may only occasionally see a few of its fruits for sale in bazaars, but is a treat for the young in rustic India is the **alu** (*Meyna laxiflora*). A small tree with opposite leaves and sharp spines, the alu yields every year a small number of brown, pulpy edible fruits the size of a table-tennis ball. The fruit ripens in May and June, and has a sour-sweet metallic taste which one has to learn to like. The nutritive value of the fruit has not been analysed though it is common enough in the Konkan and the Western Ghats. The leaves are eaten as a vegetable and used as a fodder for livestock.

The alarming rate at which our village flora is vanishing is indeed sad. Instead of lamenting, should we not replenish what is lost by planting our own indigenous trees?

S. R. AMLADI

Pagoda tree in bloom



The dominant model of disease today is biomedical, and it leaves no room within its framework for the social and psychological dimensions of illness

the need for a new medical model

GEORGE L. ENGEL

At a recent conference on psychiatric education, many psychiatrists seemed to be saying to medicine, " Please take us back and we will never again deviate from the ' medical model '." For, as one critical psychiatrist put it, " Psychiatry has become a hodgepodge of unscientific opinions, assorted philosophies and ' schools of thought ', mixed metaphores, role diffusion, propaganda, and politicking for ' mental health ' and other esoteric goals." In contrast, the rest of medicine appears neat and tidy. It has a firm base in the biological sciences, enormous technologic resources at its command, and a record of astonishing achievement elucidating mechanisms of disease and devising new treatments. It would seem that psychiatry would do well to emulate its sister medical disciplines by finally embracing once and for all the medical model of disease.

But I do not accept such a premise. Rather, I contend that all medicine is in crisis and, further, that medicine's crisis derives from the same basic fault as psychiatry's, namely, adherence to a model of disease no longer adequate for the scientific tasks and social responsibilities of either medicine or psychiatry.

Psychiatry's crisis revolves around the question of whether the categories of human distress with which it is concerned are properly considered

Jamun tree

Illustrated by Sushma

" disease " as currently conceptualised.

Medicine's crisis stems from the logical inference that since " disease " is defined in terms of somatic parameters, physicians need not be concerned with psychosocial issues which lie outside medicine's responsibility and authority. At a recent Rockefeller Foundation seminar on the concept of health, one authority urged that medicine " concentrate on the ' real ' diseases and not get lost in the psychosociological underbrush. The physician should not be saddled with problems that have arisen from the abdication of the theologian and the philosopher ".

Psychiatrists have responded to their crisis by embracing two ostensibly opposite positions. One would simply exclude psychiatry from the field of medicine, while the other would adhere strictly to the " medical model " and limit psychiatry's field to behavioural disorders consequent to brain dysfunction. The first is exemplified in the writings of Szasz and others who advance the position that " mental illness is a myth " since it does not conform with the accepted concept of disease. [T. S. Szasz, *The Myth of Mental Illness* (1961); E. F. Torrey, *The Death of Psychiatry* (1974).] Supporters of this position advocate the removal of the functions now performed by psychiatry from the conceptual and professional jurisdiction of medicine and their reallocation to a new discipline based on behavioural science. Henceforth medicine would be responsible for the treatment and cure of disease, while the new discipline would be concerned with the reeducation of people with " problems of living ". Disorders directly ascribable to brain disorder would be taken care of by neurologists, while psychiatry as such would disappear as a medical discipline.

In sum, psychiatry struggles to clarify its status within the mainstream of medicine, if indeed it belongs in medicine at all. The criterion by which this question is supposed to be resolved rests on the degree to which the field of activity of psychiatry is deemed congruent with the existing medical model of disease. But crucial to this problem is another, that of whether the contemporary model is, in fact, any longer adequate for medicine, much less for psychiatry. For, if it is not, then perhaps the crisis of psychiatry is part and parcel of a larger crisis that has its roots in the model itself.

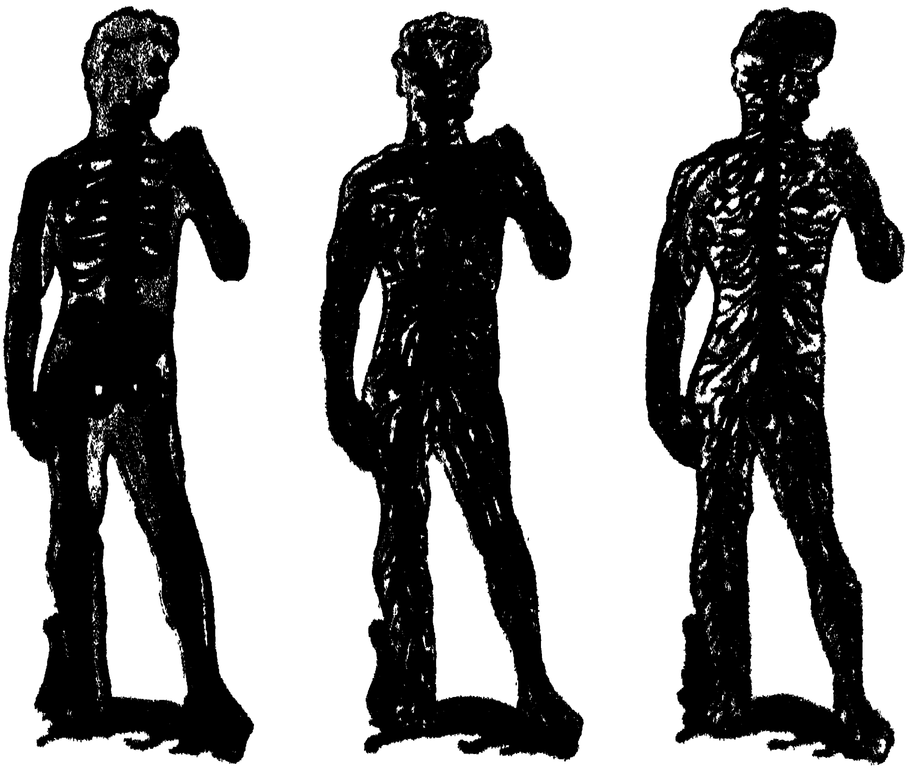
The biomedical model

The dominant model of disease today is biomedical, with molecular biology its basic scientific discipline. It assumes disease to be fully accounted for by deviations from the norm of measurable biological (somatic) variables. It leaves no room within its framework for the social, psychological and behavioural dimensions of illness. The biomedical model not only requires that disease be dealt with as an entity independent of social behaviour, it also demands that behavioural aberrations be explained on the basis of disordered somatic (biochemical or neurophysiological) processes. Thus, the biomedical model embraces both reductionism, the philosophic view that complex phenomena are ultimately derived from a single primary principle, and mind-body dualism, the doctrine that separates the mental from the somatic.

The biomedical model was devised by medical scientists for the study of disease. As such it was a scientific model; that is, it involved a shared set of assumptions and rules of conduct based on the scientific method and constituted a blueprint for research. As H. Fabrega has pointed out, " disease " in its generic sense is a linguistic term used to refer to a certain class of phenomena that members of all social groups, at all times in the history of man, have been exposed to. " When people of various intellectual and cultural persuasions use terms analogous to ' disease,' they have in mind, among other things, that the phenomena in question involve a person-centred, harmful, and undesirable deviation or discontinuity . . . associated with impairment or discomfort." Since the condition is not desired, it gives rise to a need for corrective actions. The latter involve beliefs and explanations about disease as well as rules of conduct to rationalise treatment actions.

Such culturally derived belief systems about disease also constitute models, but they are not scientific models. These may be referred to as popular or folk models. As efforts at social adaptation, they contrast with scientific models, which are primarily designed to promote scientific investigation. The historical fact we have to face is that in modern Western society, biomedicine not only has provided a basis for the scientific study of disease, it has also become our own culturally specific perspective about disease, that, is, our folk model.

In our culture, the áttitudes and belief systems of physicians are moulded by this model long before they embark on their professional education, which in turn reinforces it without necessarily clarifying how its use for social adaptation contrasts with its use for scientific research. The biomedical model has thus become a cultural imperative, its limitations easily overlooked. In brief, it has now acquired the status of *dogma*. In science, a model is revised or abandoned when it fails to account adequately for all the data. A dogma, on the other hand, requires that discrepant data be forced to fit the model or be excluded. Biomedical dogma requires that all disease, including " mental " disease, be conceptualised in terms of derangement of underlying physical mechanisms. This permits only two alternatives



whereby behaviour and disease can be reconciled: the reductionist, which says that all behavioural phenomena of disease must be conceptualised in terms of physicochemical principles; and the exclusionist, which says that whatever is not capable of being so explained must be excluded from the category of disease.

The reductionists concede that some disturbances in behaviour belong in the spectrum of disease. They categorise these as mental diseases and designate psychiatry as the relevant medical discipline. The exclusionists regard mental illness as a myth and would eliminate psychiatry from medicine. Among physicians and psychiatrists today the reductionists are the true believers, the exclusionists are the apostates, while both condemn as heretics those who dare to question the ultimate truth of the biomedical model and advocate a more useful model.

In all societies, ancient and modern, preliterate and literate, the major criteria for identification of disease have always been behavioural, psychological and social in nature. Classically, the onset of disease is marked by changes in physical appearance that frighten, puzzle, or awe, and by alterations in functioning, in feelings, in performance, in behaviour, or in relationships that are experienced or perceived as threatening, harmful, unpleasant, deviant, undesirable, or unwanted. Reported verbally or demonstrated by the sufferer or by a witness, these constitute the primary data upon which are based first-order judgments as to whether or not a person is sick. To such disturbing behaviour and reports all societies typically respond by designating individuals and evolving social institutions whose primary function is to evaluate, interpret, and provide corrective measures. Medicine as an institution and as a discipline, and physicians as professionals, evolved as one form of response to such social needs. In the course of history, medicine became scientific as physicians and other scientists developed a taxonomy and applied scientific methods to the understanding, treatment and prevention of disturbances which the public first had designated as " disease " or " sickness ".

Why did the reductionistic, dualistic biomedical model evolve in the West? H. Rasmussen identifies one source in the concession of established Christian orthodoxy to permit dissection of the human body some five centuries ago. Such a concession was in keeping with the Christian view of the body as a weak and imperfect vessel for the transfer of the soul from this world to the next. Not surprisingly, the Church's permission to study the human body included a tacit interdiction against corresponding scientific investigation of man's mind and behaviour. For, in the eyes of the Church these had more to do with religion and the soul and hence properly remained its domain.

This compact may be considered largely responsible for the anatomical and structural base upon which scientific Western medicine eventually was to be built. For, at the same time, the basic principle of the science of the day, as enunciated by Galileo, Newton and Descartes, was analytical, meaning that entities to be investigated be resolved into isolable causal chains or units, from which it was assumed that the whole could be understood, both materially and conceptually, by reconstituting the parts. With mind-body dualism firmly established under the imprimatur of the Church, classical science readily fostered the notion of the body as a machine, of disease as the consequence of breakdown of the machine, and of the doctor's task as repair of the machine. Thus, the scientific approach to disease began by focusing in a fractional-analytic way to biological (somatic) processes and ignoring the behavioural and psychosocial. This was so even though in practice many physicians, at least until the beginning of the 20th century, regarded emotions as important for the development and course of disease.

Limitations of the biomedical model

We are now faced with the necessity and the challenge to broaden the approach to disease to include the psychosocial without sacrificing the enormous advantages of the biomedical approach. In a recent critique of the exclusionist position, Kety put the contrast between the two in such a way as to help define the issues: "According to the medical model, a human illness does not become a specific disease all at once and is not equivalent to it. The medical model of an illness is a process that moves from the recognition and palliation of symptoms to the characterisation of a specific disease in which the etiology and pathogenesis are known and treatment is rational and specific." [S. Kety, *Am. J. Psychiatry*, **131,** 957 (1974).] Thus, taxonomy progresses from symptoms, to clusters of symptoms, to syndromes, and finally to diseases with specific pathogenesis and pathology. This sequence accurately

Art and Anatomy

"Anatomy showed the first stirrings of a new life at the beginning of the fourteenth century, when the first records of original human dissections begin to appear. In 1316, Mondinus published his *Anathomia*, which nudged the subject out of the Arabian twilight. . . . It was not, however, until the middle of the century that the practice of dissection received official sanction.

"Medical students were not the only individuals of the Italian quattrocento interested in anatomy. An avid interest was also shown by the painters and sculptors. It has been suggested that

describes the successful application of the scientific method to the elucidation and the classification into discrete entities of disease in its generic sense.

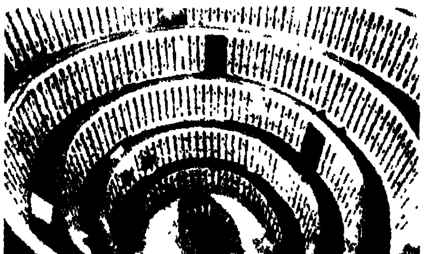
Kety approaches this problem by comparing diabetes mellitus and schizophrenia as paradigms of somatic and mental diseases, pointing out the appropriateness of the medical model for both. " Both are symptom clusters or syndromes, one described by somatic and biochemical abnormalities, the other by psychological. Each may have many etiologies and shows a range of intensity from severe and debilitating to latent or borderline. There is also evidence that genetic and environmental influences operate in the development of both."

the initial point of contact between these otherwise two disparate groups was the apothecary's shop. Here the physician would come for his specifics and the artist for his pigments. The interest of the artist in surface anatomy would lead him to accompany his new acquaintance to the still rather infrequent public anatomies. Later, in their ardent pursuit of naturalism, the artists themselves began to make dissections. So far as is known, the earliest instance of an eminent artist-anatomist is Donatello (1386-1466). . . .

"Perhaps too much should not be made of this conjunction of anatomists and artists. For, with the gigantic exception of Leonardo himself, the painters, almost by definition, were interested only in superficial anatomy. With Leonardo, however, we meet an altogether different phenomenon. . . . He was not content merely to record what he saw, but sought always to go further and attempt to understand how the body functioned. Indeed, so enthusiastic an engineer as Leonardo could hardly escape treating the body as a divine machine. In drawing after drawing after drawing we see him endeavouring to show with his crayon how part acted upon part, how muscle acted on bone, how bone articulated with bone. . . .

" Leonardo's work, however, was not published during his lifetime nor for centuries thereafter. Although it was known to exist, it seems to have had little or no influence on the subsequent history of anatomy. . . . Anatomists consequently followed their own plodding paths. Leonardo, the eagle, remained largely unknown and the tradition from Mondinus passed through Berengaria da Capri (c. 1460-1530) to the young Andreas Vesalius (1514-1564)."

— C.U.M. Smith (*The Problem of Life*, 1976)



(Left) A page from Leonardo's anatomical drawings. (Right) The first permanent anatomy theatre was completed in Padua in Italy in 1594, 75 years after Leonardo's death

Requirements of a new medical model

To explore the requirements of a medical model that would account for the reality of diabetes and schizophrenia as human experiences as well as disease abstractions, let us expand Kety's analogy by making the assumption that a specific biochemical abnormality capable of being influenced pharmacologically exists in schizophrenia as well as in diabetes — certainly a plausible possibility. By obliging ourselves to think of patients with diabetes, a " somatic disease", and with schizophrenia, a " mental disease ", in exactly the same terms, we will see more clearly how inclusion of somatic and psychosocial factors is indispensable for both; or more pointedly, how concentration on the biomedical and exclusion of the psychosocial distorts perspectives and even interferes with patient care.

(1) In the biomedical model, demonstration of the specific biochemical deviation is generally regarded as a specific diagnostic criterion for the disease. Yet, in terms of the human experience of illness, laboratory documentation may only indicate disease potential, not the actuality of the disease at the time. The abnormality may be present, yet the patient not be ill. Thus, the presence of the biochemical defect of diabetes or schizophrenia at best defines a necessary but not a sufficient condition for the occurrence of the human experience of the disease — the illness. Thus, while the diagnosis of diabetes is first suggested by certain core clinical manifestations, for example, polyuria, polydipsia, polyphagia, and weight loss, and is then confirmed by laboratory documentation of relative insulin deficiency, how these are experienced and how they are reported by any one individual, and how they affect him, all require consideration of psychological, social and cultural factors, not to mention other concurrent or complicating biological factors.

(2) Establishing a relationship between particular biochemical processes and the clinical data of illness requires a scientifically rational approach to behavioural and psychosocial data, for these are the terms in which most clinical phenomena are reported by patients. Many verbal expressions derive from bodily experiences early in life, resulting in a significant degree of ambiguity in the language patients use to report symptoms. Hence the same words may serve to express psychological as well as bodily disturbances, both of which may coexist and overlap in complex ways. Thus, virtually each of the symptoms classically associated with diabetes may also be expressions of or reactions to psychological distress, just as ketoacidosis and hypoglycemia may induce psychiatric manifestations, including some considered characteristic of schizophrenia. The most essential skills of the physician involve the ability to elicit accurately and then analyse correctly the patient's verbal account of his illness experience. The biomedical model ignores both the rigour required to achieve reliability in the interview process and the necessity to analyse the meaning of the patient's report in psychological, social, and cultural, as well as in anatomical, physiological or biochemical terms.

(3) Diabetes and schizophrenia have in common the fact that psychophysiologic responses to life change may interact with existing somatic factors to alter susceptibility and thereby influence the time of onset, the severity, and the course of a disease.

(4) Psychological and social factors are also crucial in determining whether and when patients with the biochemical abnormality of diabetes or of schizophrenia come to view themselves or be viewed by others as sick. Still other factors of a similar nature influence whether or not and when any individual enters a health care system and becomes a patient. Thus, the biochemical defect may determine certain characteristics of the disease, but not necessarily the point in time when the person falls ill or accepts the sick role or the status of a patient.

(5) " Rational treatment " (Kety's term) directed only at the biochemical abnormality does not necessarily restore the patient to health even in the face of documented correction or major alleviation of the abnormality. This is no less true for diabetes than it will be for schizophrenia when

a biochemical defect is established. Other factors may combine to sustain patienthood even in the face of biochemical recovery.

(6) Even with the application of rational therapies, the behaviour of the physician and the relationship between patient and physician powerfully influence therapeutic outcome for better or for worse. These constitute psychological effects which may directly modify the illness experience or indirectly affect underlying biochemical processes. Thus, insulin requirements of a diabetic patient may fluctuate significantly depending on how the patient perceives his relationship with his doctor. Furthermore, the successful application of rational therapies is limited by the physician's ability to influence and modify the patient's behaviour in directions concordant with health needs. Contrary to what the exclusionists would have us believe, the physician's role is, and always has been, very much that of educator and psychotherapist.

The boundaries between health and disease, between well and sick, are far from clear and never will be clear, for they are diffused by cultural, social and psychological considerations. The traditional biomedical view, that biological indices are the ultimate criteria defining disease, leads to the present paradox that some people with positive laboratory findings are told that they are in need of treatment when in fact they are feeling quite well, while others feeling sick are assured that they are well, that is, they have no " disease ". A biopsychosocial model which includes the patient as well as the illness would make it possible to explain why some individuals experience as " illness " conditions which others regard merely as " problems of living ", be they emotional reactions to life circumstances or somatic symptoms. Indeed, some people deny the unwelcome reality of illness by dismissing as " a problem of living " symptoms which may in actuality be indicative of a serious organic process. It is the doctor's, not the patient's, responsibility to establish the nature of the problem and to decide whether or not it is best handled in a medical framework.

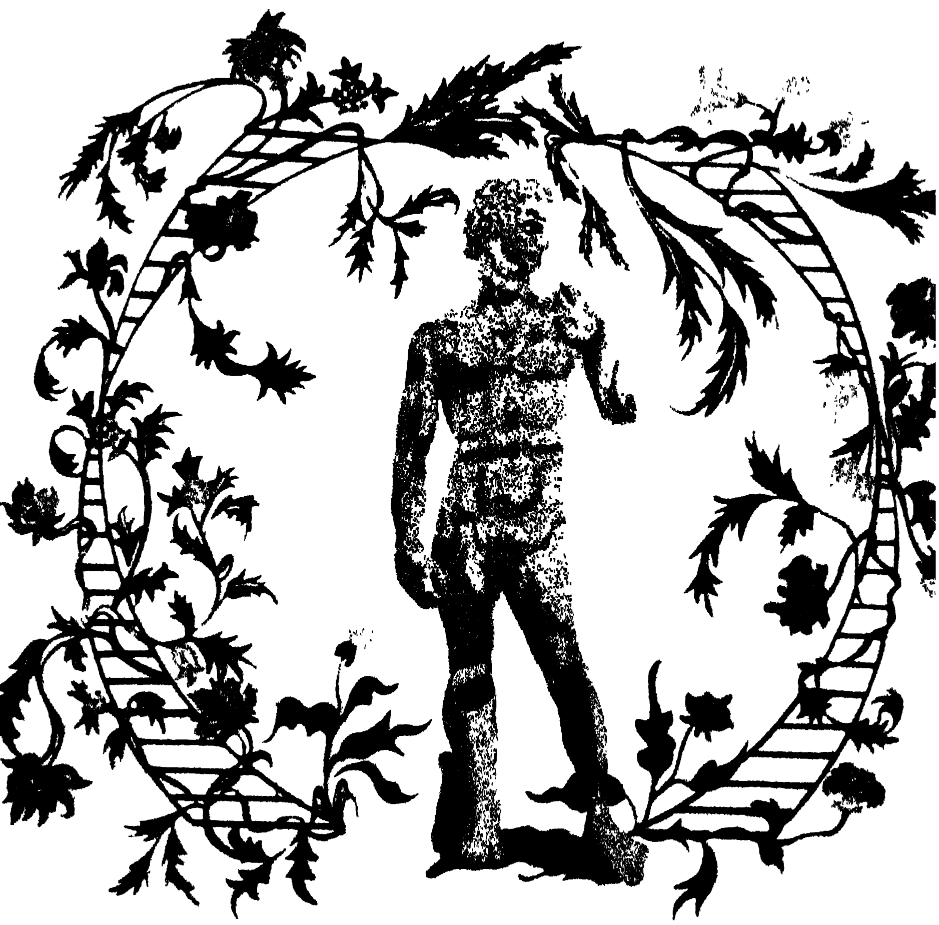
When is grief a disease?

To enhance our understanding of how it is that " problems of living " are experienced as illness by some and not by others, it might be helpful to consider grief as a paradigm of such a borderline condition. For while grief has never been considered in a medical framework, a significant number of grieving people do consult doctors because of disturbing symptoms, which they do not necessarily relate to grief. Fifteen years ago, I addressed this question in a paper entitled " Is grief a disease? A challenge for medical research ". Its aim, too, was to raise questions about the adequacy of the biomedical model. A better title might have been, " When is grief a disease? ", just as one might ask when schizophrenia or when diabetes is a disease? For while there are some obvious analogies between grief and disease, there are also some important differences.

Grief clearly exemplifies a situation in which psychological factors are primary; no pre-existing chemical or physiological defects or agents need be invoked. Yet, as with classic diseases, ordinary grief constitutes a discrete syndrome with a relatively predictable symptomatology which includes, incidentally, both bodily and psychological disturbances. It displays the autonomy typical of disease; that is, it runs its course despite the sufferer's efforts or wish to bring it to a close.

On the face of it, the arguments against including grief in a medical model would seem to be the more persuasive. In the 1961 paper, I countered these by comparing grief to a wound. Both are natural responses to environmental trauma, one psychological, the other physical. But even at the time I felt a vague uneasiness that this analogy did not quite make the case. Now 16 years later a better grasp of the cultural origins of disease concepts and medical care systems clarifies the apparent inconsistency. The critical factor underlying man's need to develop folk models of disease, and to develop social adaptations to deal with the individual and group disruptions brought about by disease, has always been the victim's ignorance of what is responsible for his dysphoric disturbing experience. Neither grief nor a wound fits fully into that category. In both, the reasons for the pain, suffering and disability are only too clear.

Wounds or fractures incurred in battle or by accident by and large were self-treated or ministered to with folk remedies or by individuals who had acquired certain technical skills in such matters. Surgery developed out of the need for treatment of wounds and injuries and has different historical roots than medicine, which was always closer in origin to magic and religion. Only later in Western history did surgery and medicine merge as healing arts. But even from earliest times there were people who behaved as though grief-stricken, yet seemed not to have suffered any loss; and others who developed what for all the world looked like wounds or fractures, yet had not been subjected to any known trauma. And there were



people who suffered losses whose grief deviated in one way or another from what the culture had come to accept as the normal course; and others whose wounds failed to heal or festered or who became ill even though the wound had apparently healed. Then, as now, two elements were crucial in defining the role of patient and physician and hence in determining what should be regarded as disease. For the patient it has been his not knowing why he felt or functioned badly or what to do about it, coupled with the belief or knowledge that the healer or physican did know and could provide relief. For the physician, in turn, it has been his commitment to his professional role as healer. From these have evolved sets of expectations which are reinforced by the culture, though these are not necessarily the same for patient as for physician.

The psychobiological unity of man requires that the physician accept the responsibility to evaluate whatever problems the patient presents and recommend a course of action, including referral to other helping professions. Hence the physician's basic professional knowledge and skills must span the social, psychological and biological, for his decisions and actions on the patient's behalf involve all three. Is the patient suffering normal grief or melancholia? Are the fatigue and weakness of the woman who recently lost her husband conversion symptoms, psychophysiological reactions, manifestations of a somatic disorder, or a combination of these? The patient soliciting the aid of a physician must have confidence that the MD degree has indeed rendered that physician competent to make such differentiations.

A challenge for both medicine and psychiatry

The development of a biopsychosocial medical model is posed as a challenge for both medicine and psychiatry. For despite the enormous gains which have accrued from biomedical research, there is a growing uneasiness among the public as well as among physicians, and especially among the younger generation, that health needs are not being met and that biomedical research is not having a sufficient impact in human terms. This is usually ascribed to the all too obvious inadequacies of existing health care delivery systems. But this certainly is not a complete explanation, for many who do have adequate access to health care also complain that physicians are lacking in interest and understanding, are preoccupied with procedures, and are insensitive to the personal problems of patients and their families. Medical institutions are seen as cold and impersonal; the more prestigious they are as centres for biomedical research, the more common such complaints.

Head of a Lost Soul, black chalk drawing by Michelangelo

Like his contemporaries including Leonardo, Michelangelo, too, exulted in the beauty of the human form and painted and sculpted bodies with a profound knowledge of anatomy. The supreme example, perhaps, was the gigantic marble sculpture *David* (adapted as motif in the colour illustrations in the preceding pages). In the *Head of a Lost Soul*, Michelangelo steps into the " Church's domain ".

The present upsurge of interest in primary care and family medicine clearly reflects disenchantment among some physicians with an approach to disease that neglects the patient. They are now more ready for a medical model which would take psychosocial issues into account. Even from within academic circles are coming some sharp challenges to biomedical dogmatism. Thus Holman ascribes directly to biomedical reductionism and to the professional dominance of its adherents over the health care system such undesirable practices as unnecessary hospitalisation, overuse of drugs, excessive surgery, and inappropriate utilisation of diagnostic tests. [H. R. Holman, *Hosp. Prac.*, **11,** 11 (1976).] How ironic it would be were psychiatry to insist on subscribing to a medical model which some leaders in medicine already are beginning to question.

Psychiatrists, unconsciously committed to the biomedical model and split into the warring camps of reductionists, are today so preoccupied with their own professional identity and status in relation to medicine that many are failing to appreciate that psychiatry now is the only clinical discipline within medicine concerned primarily with the study of man and the human condition. Indeed, the fact is that the major formulations of more integrated and holistic concepts of health and disease proposed in the past 30 years have come not from within the biomedical establishment but from physicians who have drawn upon concepts and methods which originated within psychiatry, notably the psychodynamic approach of Sigmund Freud and psychoanalysis and the reaction-to-life-stress approach of Adolf Meyer and psychobiology. Actually, one of the more lasting contributions of both Freud and Meyer has been to provide frames of reference whereby psychological processes could be included in a concept of disease.

Psychosomatic medicine — the term itself a vestige of dualism — became the medium whereby the gap between the two parallel but independent ideologies of medicine, the biological and the psychosocial, was to be bridged. Its progress has been slow and halting, not only because of the extreme complexities intrinsic to the field itself, but also because of unremitting pressures, from within as well as from without, to conform to scientific methodologies basically mechanistic and reductionistic in conception and inappropriate for many of the problems under study. Nonetheless, by now a sizable body of knowledge, based on clinical and experimental studies of man and animals has accumulated. Most, however, remains unknown to the general medical public and to the biomedical community and is largely ignored in the education of physicians.

The fact is that medical schools have constituted unreceptive if not hostile environments for those interested in psychosomatic research and teaching, and medical journals have all too often followed a double standard in accepting papers dealing with psychosomatic relationships. Further, much of the work documenting experimentally in animals the significance of life circumstances or change in altering susceptibility to disease has been done by experimental psychologists and appears in psychology journals rarely read by physicians or basic biomedical scientists.

Biomedicine as science and as dogma

What is being and can be done to neutralise the dogmatism of biomedicine and all the undesirable social and scientific consequences that flow therefrom? How can the clinician be helped to understand the extent to which his scientific approach to patients represents a distinctly " human science ", one in which " reliance is on the integrative powers of the observer of a complex nonreplicable event and on the

experiments that are provided by history and by animals living in particular ecological settings", as Margaret Mead puts it?

The history of the rise and fall of scientific dogmas throughout history may give some clues. Certainly, mere emergence of new findings and theories rarely suffices to overthrow well-entrenched dogmas. The power of vested interests — social, political and economic — are formidable deterrents to any effective assault on biomedical dogmatism. The delivery of health care is a major industry, considering that more than 8 per cent of our [US] national economic product is devoted to health. The enormous existing and planned investment in diagnostic and therapeutic technology alone strongly favours approaches to clinical study and care of patients that emphasise the impersonal and the mechanical. For example, from 1967 to 1972, there was an increase of 33 per cent in the number of laboratory tests conducted per hospital admission. Planning for systems of medical care and their financing are excessively influenced by the availability and promise of technology, the application and effectiveness of which are often used as the criteria by which decisions are made as to what constitutes illness and who qualifies for medical care.

The professionalisation of biomedicine constitutes still another formidable barrier. Professionalisation has engendered a caste system among health care personnel and a peck order concerning what constitute appropriate areas for medical concern and care, with the most esoteric disorders at the top of the list. Professional dominance " has perpetuated prevailing practices, deflected criticisms, and insulated the profession from alternate views and social relations that would illuminate and improve health care " [Holman].

Under such conditions it is difficult to see how reforms can be brought about. Certainly, contributing another critical essay is hardly likely to bring about any major changes in attitude. The problem is hardly new, for the first efforts to introduce a more holistic approach into the undergraduate medical curriculum actually date back to Adolph Meyer's programme at Johns Hopkins, which was initiated before 1920. At Rochester, a programme directed to medical students and to physicians during and after their residency training, and designed to inculcate psychosocial knowledge and skills appropriate for their future work as clinicians or teachers, has been in existence for 30 years. While difficult to measure outcome objectively, its impact, as indicated by a questionnaire on how students and graduates view the issues involved in illness and patient care, appears to have been appreciable. In other schools, especially in the immediate post-World War II period, similar efforts were launched, and while some flourished briefly, most soon faded away under the competition of more glamorous and acceptable biomedical careers. Today, within many medical schools there is again a revival of interest among some faculty, but they are few in number and lack the influence, prestige, power, and access to funding from peer review groups that goes with conformity to the prevailing biomedical structure.

Yet today, interest among students and young physicians is high, and where learning opportunities exist they quickly overwhelm the available meagre resources. It would appear that given the opportunity, the younger generation is very ready to accept the importance of learning more about the psychosocial dimensions of illness and health care and the need for such education to be soundly based on scientific principles. Once exposed to such an approach, most recognise how ephemeral and insubstantial are appeals to humanism and compassion when not based on rational principles.

Clearly, the gap to be closed is between teachers ready to teach and students eager to learn. But nothing will change unless or until those who control resources have the wisdom to venture off the beaten path of exclusive reliance on biomedicine as the only approach to health care. The proposed biopsychosocial model provides a blueprint for research, a framework for teaching, and a design for action in the real world of health care. Whether it is useful or not remains to be seen. But the answer will not be forthcoming if conditions are not provided to do so. In a free society, outcome will depend upon those who have the courage to try new paths and the wisdom to provide the necessary support.

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[The original expanded version of the article, adapted from material presented as lectures at various US institutions in 1976, appeared in *Science*, 196, 129–136, 8 April 1977. © 1977 American Association for the Advancement of Science.]

IN LIGHTER MOMENTS

The American palaeontologists Othniel Charles Marsh and Edward Drinker Cope were always at loggerheads. Because of their competitive hurry to produce more papers, the feud between the two resulted in many mistakes and often put them into a rather comic plight. Thus, when Cope, mounting the skeleton of a 14 metre swimming lizard, *Elasmosaurus platyurus*, put its head on the wrong end, Marsh immediately pounced on Cope's mistake. Cope retaliated by pointing out that Marsh had mistaken a horned lizard for a bison. Ultimately things came to such a head that they aired their grievances in the local newspapers. A local poetaster writing on behalf of Cope, addressed Marsh thus:

You stole your evoluted horse from Kovalesky's brain,
And previous people's fossils smashed from Mexico to Maine.

To which Marsh replied —

Your reference to a horncone on an ischium sends a chill
Professor Huxley is my friend and so is Buffalo Bill

(Buffalo Bill Cody had spent a day with Marsh's party in 1870 and later accompanied him on some of his expeditions.)

Major John Powell, of the US Geological Survey, joined the fray by attacking Cope

Through natural selection's law you are, as I'm alive,
Of all survivals found, the least fit to survive

*

Karl Landsteiner, discoverer of the A, B and O blood types in man, was sceptical of the efficacy of electrophoresis for distinguishing and separating closely related chemical substances. However, when Lewis G Longsworth, of the Rockefeller Institute, demonstrated to him its sensitivity by separating a mixture of guinea hen and duck albumins, Landsteiner became such an ardent proponent that he submitted everything that came his way to electrophoresis, and was always on the lookout for new material to test.

One day he stopped a man leading a donkey along a New York street with a request for some of the donkey's blood for sampling. The donkey-driver, however, refused, saying, " This donkey is going on the stage of the Metropolitan Opera and cannot afford to lose any blood ! "

*

Particles or waves? The argument on the nature of light has been raging for long. An indication of the complexity of its nature is revealed in the statement by the famous physicist, Sir William Bragg: " Light behaves like waves on Mondays, Wednesdays and Fridays, like particles on Tuesdays, Thursdays and Saturdays, and like nothing at all on Sundays."

B. F. CHHAPGAR

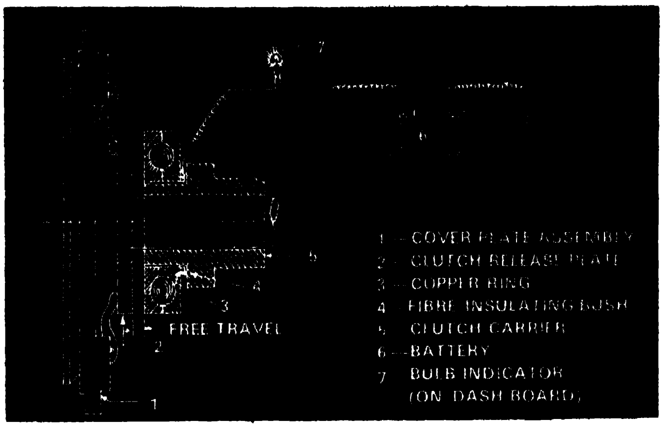
Free-travel indicator for heavy dumpers

Free-travel, the initial free movement of the release bearing until it contacts the release lever plate, is essential for effective operation of the driven disc clutch system used in vehicles. However, as a result of the wearing out of the clutch discs, the free-travel continuously decreases and the release lever plate keeps on moving closer to the release bearing, until the two jam against each other in a sort of a permanent embrace. Such a situation leads to continuous clutch wearing out, thrust on the crankshaft, and gradual overheating of the clutch and the engine.

This free-travel, also called the 'air gap' that isolates the release bearing from the release lever plate, must, therefore, be checked and adjusted frequently by vehicle operators. However, unlike the drivers of transport vehicles, the operators of heavy vehicle dumpers cannot perceptibly feel the free-travel gap simply by depressing the pedal, because the dumpers are equipped with heavy-duty, air-assisted clutches designed to transmit as much as 300 HP.

Mr. B. R. Chadha, Area Superintendent, Beas-Sutlej Link Project, has now come up with a new device especially designed to warn the operators of heavy vehicle dumpers about the impending trouble in respect of free-travel. It is essentially an electrical circuit — normally open — which closes whenever the air gap becomes zero — that is, when the release lever plate makes a metal-to-metal contact with the release bearing. When the circuit closes, a small indicator bulb automatically lights up for the duration of the contact. If the free-travel is completely absent, the plate-bearing contact will be permanent and there will be a constant glow of the indicator bulb. The device thus keeps the operator posted about the condition of the free-travel gap.

To fit the new device on a heavy vehicle dumper, a small modification of the release bearing carrier is necessary: it has to be electrically insulated from the bearing by inserting a 1·5-mm thick bush of bakelite or ebonite in between the two. An insulated wire from the release bearing is then connected to one of the terminals of a battery, the other being earthed to complete the circuit. A small 12 V bulb is mounted on the dashboard and put in series in the circuit. The new device is fool-proof, says Mr. Chadha. Even grease or oil which has leaked over the bush does not affect the insulation or the working of the system. The device costs only Rs 100 per unit.



BADIUDDIN KHAN

High heat flux surfaces

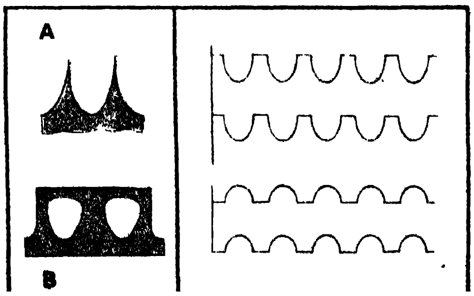
High heat flux surfaces, plane or circular pipes, have been recently developed for obtaining a higher rate of heat transfer for a given wall superheat. Such surfaces have, specifically, been found to be useful for boiling and condensation. In boiling, it has been observed that for polished surfaces and pure liquids (not containing any dissolved gases), the wall superheat (difference between wall temperature and saturation temperature of the liquid, see box) required to start boiling is quite appreciable. The boiling sites also, when boiling gets initiated, are not uniformly distributed over the whole boiling surface. Besides, the wall temperature needs to be fairly high before any of the microcavities get activated for boiling. On a smooth surface, for example, stainless steel or glass, there are hardly any surface defects or cavities; as a result, one requires to heat the surface to a fairly high temperature before boiling starts. Artificially roughened surfaces or surfaces having defects during their preparation contain cavities of varied sizes below them which can get activated.

There are applications, especially in refrigeration and air or gas fractionation, where the wall superheat available, or which can be made available, is quite small. That boiling can be initiated and the rate of heat transfer can be fairly high even with low wall superheats is a great advantage for many of these applications. If high flux surfaces, where this can be achieved, are available cheaply (which is not the case), even day-to-day boiling applications can be considered.

In principle, high flux surfaces are obtained by shaping out saw-toothed or similarly shaped protrusions in rows (with pitch of a millimetre or less) very close to one another, but in a definite orientation, depending on the application, a metal plate or tube, by means of a specially designed tool. The protrusions, when they cover the entire surface, act as fins with pointed edges and help in obtaining dropwise condensation; this, in turn, increases the heat flux. (There are two types of condensation on a metal surface — film condensation and dropwise condensation. In film condensation, the liquid condenses in the form of a film, which reduces further heat transfer. In dropwise condensation, the vapour condenses in the form of drops; heat flux for dropwise condensation is appreciably more than it is for film condensation.) The grooves between different rows serve to store the condensate temporarily which trickles in the form of drops leading to dropwise condensation. The sketch below shows the protrusions with the length and pitch.

These saw-toothed sharp edges are folded in a transverse direction to give a structure similar to the one given in Fig. B. This folded structure below

Fig. A (top row) Two views of the saw-toothed protrusions on metal surfaces used for condensation applications
Fig. B (bottom row) Two views of the folded structure of the surfaces



the surface helps in trapping the vapour below the surface, and a continuous stream of bubbles is ensured from the artificial cavities. Moreover, relatively large cavities produced in this manner get activated even with a small wall superheat.

Such surfaces can be made out of copper, aluminium and steel. Basically, for condensation, the increase in heat flux is due to the increased surface area and dropwise condensation; for boiling, it is due to a sudden activation of artificially created cavities even with a small wall superheat. As there is a limit to the number of artificial boiling sites that can be provided due to the finite size of cavities, high wall superheats may not give much advantage. This is because there are no microcavities, which could be activated at high wall superheats, as is the case for boiling with commercial surfaces. It is expected, therefore, that the use of the so-called high flux surfaces will be limited to applications where low wall superheats are available, for instance, refrigeration and air fractionation, especially where an evaporator-condenser combination can be used. In such cases, the size of the unit would become substantially small with resultant economy in operating costs over a period of time.

S. P. MAHAJAN

THE BOILING PROCESS

It is known that heat travels from a higher temperature to a lower temperature. The higher this temperature difference, the higher would be the rate of transfer of heat. The rate of transfer of heat per unit area per unit time is called the heat flux. When a liquid is boiled, the temperature difference available (also called the wall superheat) for heat transfer is that between the hot surface and the saturation temperature of the liquid under prevailing conditions of pressure. All commercial surfaces used for boiling contain very small cavities which are micronic in dimensions, but not necessarily of the same dimension. All these cavities, big and small, are potential boiling sites, provided sufficient amount of wall superheat is made available.

The only way to increase the wall superheat, other conditions remaining the same, is to increase the temperature of the hot surface. It has been observed that less wall superheat is required to initiate boiling at bigger cavities compared to small ones. The bigger cavities are activated first, if the wall temperature of the heating surface is increased. If the temperature of the wall is further increased, more and more of the smaller cavities become active for boiling (an active boiling site is where vapour bubbles form, detach and move away such that a chain of vapour bubbles, rapidly following one another, is formed with a high frequency and the whole thing looks like a string). If the wall superheat is further increased, a stage is reached when practically all the sites, small or big, become active and the rate of transfer of heat, or the heat flux, increases very substantially even with a minute increase in the temperature of the surface. This is called fully developed boiling. With further increases in the temperature of the metal surface, there is hardly any increase in the heat flux, as the vapour covers and binds the hot surface and the insulating gas cover so obtained even reduces the heat flux.

On a smooth and polished surface, the size of the microcavities is very small. The wall temperature or the superheat of the metal surface required for starting boiling will be comparatively large. If, however, a scratch is made on this surface or the surface is artificially roughened, boiling begins even with small wall superheat. It has been further observed that if some vapour space is provided below these cavities, boiling begins even at lower wall superheats. To get an idea of wall superheats required for full boiling of water with different surfaces, the hot metal surface and the boiling temperature of water (that is, 100°C at atmospheric pressure) required for full boiling with a smooth surface may be of the order of 10°C or more. If the metal surface is filed artificially, it may be around 5°C and with a surface with artificial cavities, it may be 1°C or less.

S.P.M.

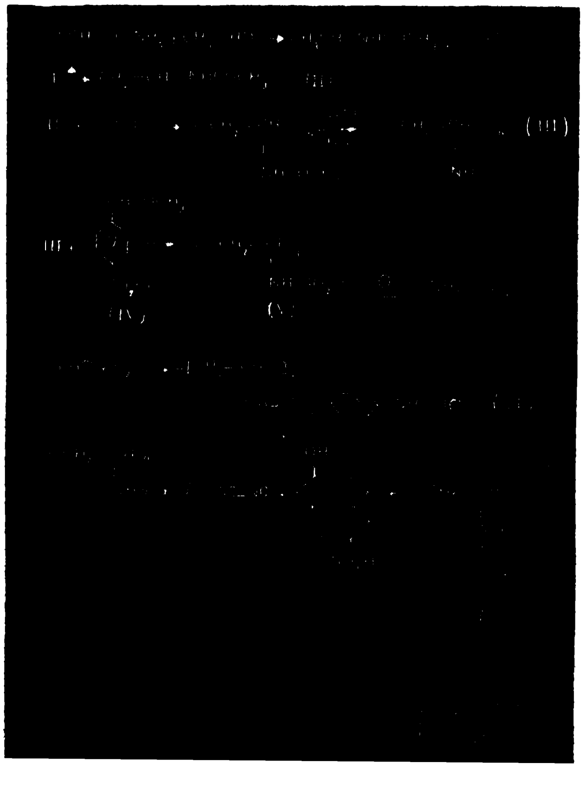
Safer food colours

One of the food additives under constant watch and attack is food colour. Though a variety of colours are claimed to be harmless, there are only a few which have proved so. And some products, which were found to be safe initially, were discovered to be harmful on longer use and, hence, discarded. Chemists use various techniques to make the colours unabsorbable in the body. One of the recent methods is to chemically attach the dye molecule to a polymer backbone. The large size of the polymer molecule inhibits the diffusion of the colour-polymer molecule through the intestine.

But the polymeric dye should have a high colour strength, solubility in the pH range 2 to 8, and still be inexpensive. The synthesis of such a polymeric dye, which can be safely used as a food colour, has been reported recently.

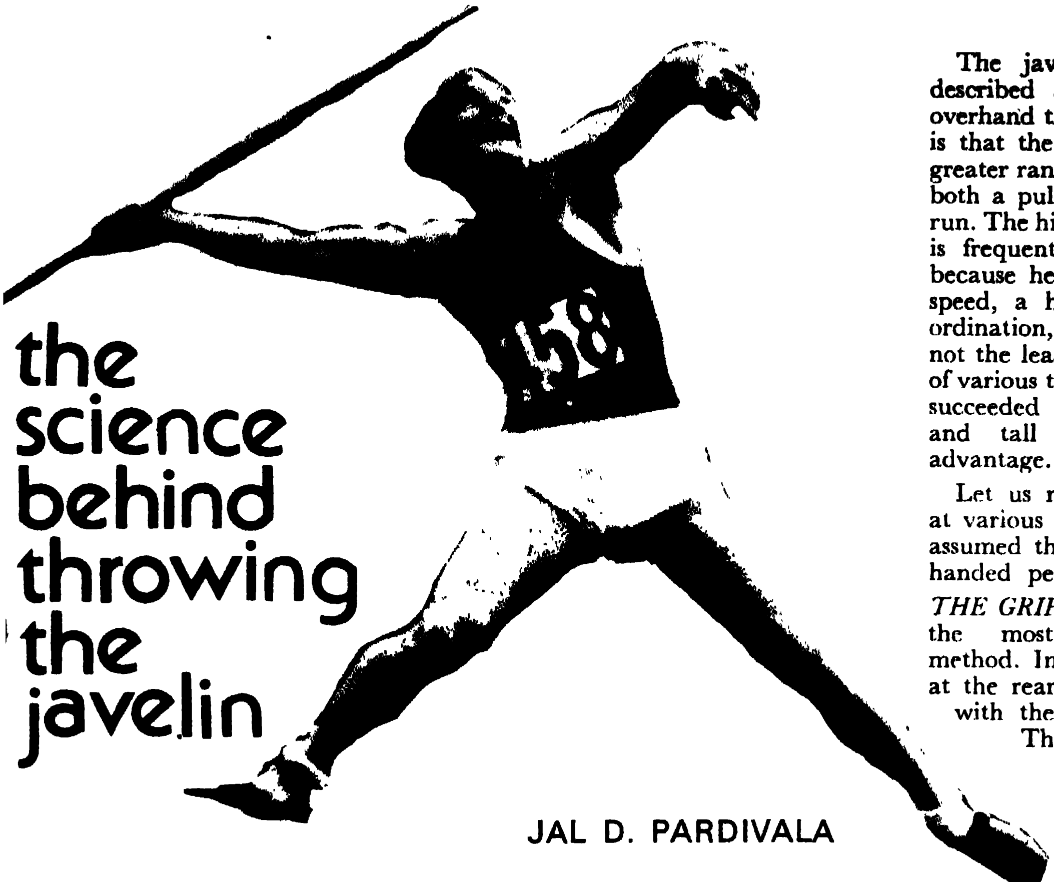
The synthesis can be divided into three parts: (*i*) formation of a polymer which has a pendent functional group, (*ii*) reacting a diazo component with the pendent group of the polymer, and (*iii*) diazotisation of the polyamine and coupling with the coupling component.

Polyvinyl amine has been used for the first part. Though various routes to make polyvinyl amine have been suggested in the literature, invariably the product is not pure and the yields are low. To overcome this, a new route to polyvinyl amine has been investigated. Vinyl acetamide is first prepared by reacting acetamide with acetaldehyde in acidic conditions to give ethylidene *bis* acetamide (I). By heating the product, vinyl acetamide (II) is obtained (90 per cent yield).



Vinyl acetamide so obtained is polymerised using a standard polymerisation initiator to give a polymer of 30,000 to 200,000 molecular weight. The polymer is boiled with hydrochloric acid to give polyvinyl amine (III). The amino group so liberated is reacted with a diazo component (N-acetylsulfanilyl chloride, IV). The polymer (V) is again hydrolysed with water and HCl to give a polyamine. Polymer (VI) is rapidly diazotised with sodium nitrite solution. The diazonium salt is coupled with alkaline sodium-2 naphthol 6-sulfonate.

V. C. MALSHE



the science behind throwing the javelin

JAL D. PARDIVALA

At one time, throwing the javelin was the monopoly of the Scandinavian countries, especially Finland, which still has 100 throwers with figures of over 70 metres (229 ft) and 150 throwers over 67 metres (220 ft). In the *Progressive World Record List Book* (prepared by the International Amateur Athletic Federation), from 1912 to date, six names of the " sons of Suomi " (Finland in its native tongue is called " Suomi ") appear. And one name, that of Matti Jarvinen, repeats itself 10 times. He came to be called " Mr. Javelin "; from August 1930 till June 1936 he kept on improving the world record — from 71·57 metres (234 ft 9 in) in 1930 to 77·23 metres (253 ft 4 in) in 1936, and collected on the way the 1932 Los Angeles Olympic Games gold medal.

Two years later, Jarvinen's protege and compatriot Yrjo Nikkanen carried the mark on to 78·70 metres (258 ft 2 in) — a record that stood unbeaten for almost 15 years until an American Franklin " Bud " Held took over the leadership. Held was chiefly responsible for the spectacular advance in javelin distances during the 1950s. He made researches into the characteristics of flight and landing attitudes of javelins and designed the first aerodynamic model.

The javelin was first introduced in the 1908 Olympic Games at London and from that year till Montreal 1976, Finland secured the gold medal five times, the silver six times, the bronze four times; 4th place eight times; 5th place thrice; and the 6th place four times. A very worthy achievement for a country the size of Rajasthan in India.

However, the greatest javelin thrower has been the Russian Janis Lusis. Melvyn Watman in his *Encyclopedia of Athletics* writes: " In an event — the javelin — in which an athlete's performance often fluctuates widely, Janis Lusis has been the personification of consistency. A combination of outstanding competitive ability over a period of many years, plus a smattering of world record throws, makes him the greatest javelin *artiste* of all time — surpassing even the achievements of Finland's Matti Jarvinen."

The most important factor in any throwing event is the *velocity of the implement as it leaves the hand.* The following figures arrived at by some mechanical engineering students are worth noting. If the weight man (shot putter) wishes to throw 15 metres (about 49 ft), the implement should leave the hand at 9·29 metres (30 ft 6 in) per second. To achieve 46 metres (about 150 ft) in discus throw, the discus should travel at 19·20 metres (63 ft.) per second; and for a 61 metre (about 200 ft) javelin throw, the speed should be 23·50 metres (about 77 ft) per second. (These figures have been worked out ignoring wind resistance and assuming that the flight is correct.)

The javelin event can best be described as a modification of the overhand throw. The main difference is that the javelin is ***pulled through*** a greater range of movement, making it both a pull and a throw following a run. The highly skilled javelin thrower is frequently an all-rounder athlete, because he must have good running speed, a high degree of motor co-ordination, good timing and, last but not the least, strength. While persons of various types of physical build have succeeded in this event, the strong and tall athlete has a decided advantage.

Let us now discuss the technique at various stages of the throw. (It is assumed that the thrower is a right-handed person.)

THE GRIP: The " Finnish grip " is the most commonly employed method. In this, the shaft is grasped at the rear end of the cord binding with the *thumb* and *second* finger. The first finger extends along and is somewhat around the shaft, while the second, third and small fingers grip the javelin around the binding. This method permits the javelin to rest in the groove of the palm (Fig. 1). In the "American method", the index finger and the thumb hold the rear end of the binding, the javelin lying in the hollow formed by the thumb and index finger (Fig. 2).

Whatever method the thrower uses, the javelin should rest in the hollow of the hand, with the wrist straight.

THE CARRY: The principle to be established is that the throwing arm must be kept *relaxed* until it starts its action of throw. If the arm is kept

Fig. 1

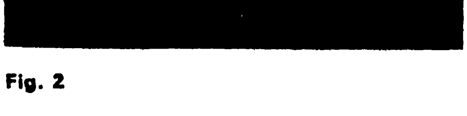


Fig. 2

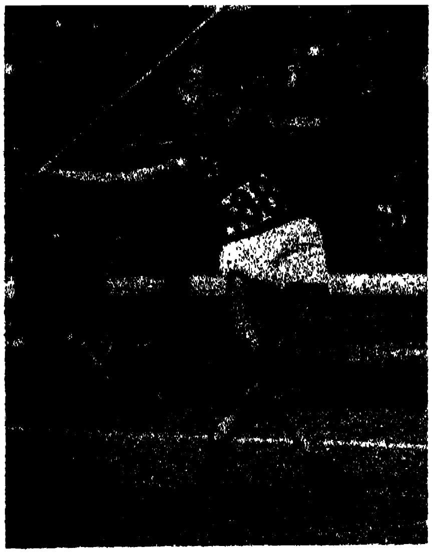


Fig. 3 The " cross-step

motionless or rigid, it will tend to tense up. Therefore, throughout the run-up and " cross-step " (Fig. 3), see that the arm is constantly in motion. The free arm with elbow bent at right angles acts as a balance in consonance with the opposite leg. (Right leg-left arm and vice versa.)

THE APPROACH: Because speed is essential to a successful performance, the javelin thrower approaches the second check mark from a distance which permits him to attain as much speed as he can *adequately control*. This mark (first) will be his starting point. The distance between these two check marks (first and second) is covered in four strides. The third check mark is at the end of the eighth stride from the second (Fig. 4). The total distance from the first check mark to the second and from the second to the third will depend on the length of the stride of each individual. The approach is relaxed and the rate of acceleration is constant. It is desirable that check marks are adjusted and standardising of strides done properly during the learning and training process. (See " The Science of The Long Jump " — ' The Approach ', Science Today, March 1977, pp. 46-47.)

It is further suggested that during training and practice, and especially while learning, a straight line is drawn in the middle and perpendicular to the side lines of the javelin throw area (Fig. 5).

THE THROWING PROCESS: The thrower stands near the first check mark with heels and toes parallel and slightly apart. The javelin is carried comfortably over the right shoulder, say, just about ear-height. The extended arm is flexed at the elbow and the tip of the javelin is *tilted towards the ground* and slightly inwards. Several coaches suggest that between check marks 1 and 2, which is the first section of the run, the thrower should put in only one-half speed. Between check marks 2 and 3, the thrower gradually accelerates, so that by the time he reaches check mark 3, the thrower is running at almost 80 to 90 per cent of his full speed. It must be pointed out here that some throwers take two extra steps for jog before they approach the first check mark.(to gather speed).

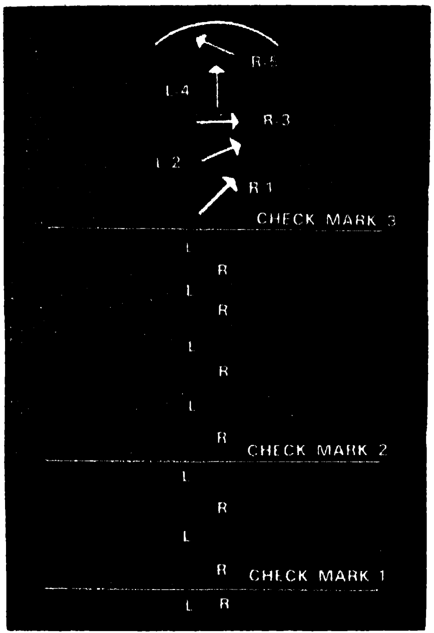


Fig. 4

THE CROSS STEP: The heart of the javelin throw technique is the "cross step". It is important and essential for two reasons. First, it initiates more drive from the throwing leg; second, it allows quicker body rotation which provides additional power for the upper body and the throwing arm. In using the "cross step", the thrower should know exactly where to begin his manoeuvre in relation to the foul line, lest he be over the line before the completion of the whole "cross-over" process. At least two metres of space from the foul line (that is, the javelin arc) should be left for the successful management of the whole movement which has to be performed with a certain momentum. Besides avoiding going over the foul line, this much space is also needed for a good and free 'reverse'. The whole process including the 'reverse' covers the last five steps.

Most coaches recommend that it is good practice to count 1, 2, 3, 4 and 5 in rhythm for the last five steps which are involved in the 'delivery' and 'reverse'.

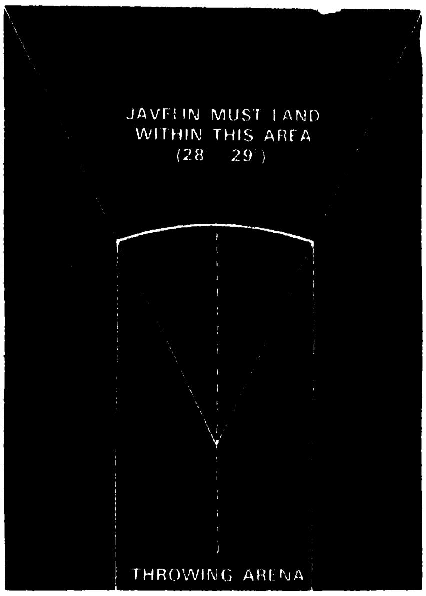
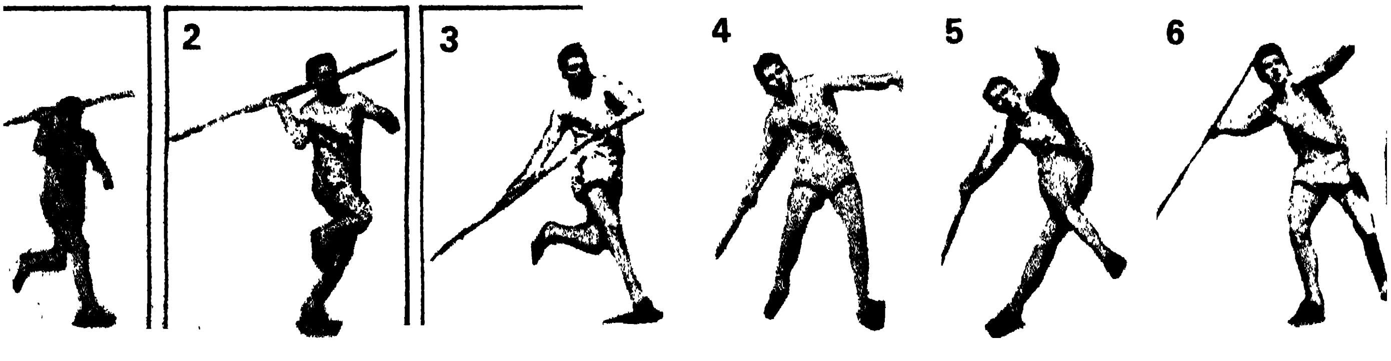


Fig. 5

After the left foot strikes check mark 3, on count 1, the right foot strikes the ground with the toes turned slightly outward. On count 2, the left foot strikes the ground, *toes pointing inwards to the right* (Figs. 4 & 6); left hip and side almost face the direction of the throw. (By this time the javelin is drifted back and down so that it is being pulled along behind the throw.) (See sequence 4 of the series in Fig. 7.) On count 3, the right leg executes a front " cross-over " step, the foot landing with the right toe pointing to the right, almost at right angles to the direction



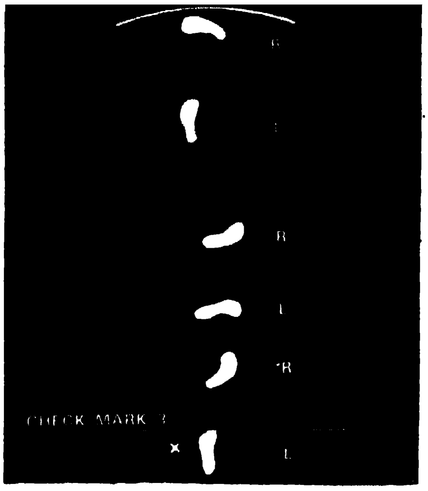


Fig. 6

of the throw (Figs. 4 & 6). At this juncture, the upper body from hips above is tilted back to enable the right leg to make a free sweep forward (sequence 5 in Fig. 7). This step is very symbolic, but also difficult to execute. By this time the javelin goes back completely.

On count 4, a good long step is taken with the left leg; it lands straight in the direction of the throw and slightly to the left, the weight of the body remaining on the right hip. According to Doherty (Track Coach, University of Pennsylvania, and author of *Modern Track and Field*), the placement of the left foot about 30 centimetres (1 ft) to the left of the line of the run necessarily means a quick forward rotation of the hips so that they are at right angles to the throw very early in the throwing action. (It is tantamount to saying that this sort of placement of the left foot brings less tension and strain on the right hip when it rotates towards the left and into the trunk at the instance of throwing.)

It is to be remembered that on no account the left leg is to be placed in the bucket, that is, further to the left.

THE THROW: We have seen how the throwing action begins — with the left foot going forward to gain the throwing stance, the javelin in the right arm back but not fully stretched. If properly co-ordinated and executed, " the cross-over " step with the right and a long stride with the left leg puts the body in a position with the arm and shoulders tilted back. This position subsequently permits a "blast" action.

Just at the instant when the left foot is firmly planted on count 4, the right hip drives forward, rotating towards the left and into the trunk. At this point, the right shoulder is brought forward, with the left arm thrust out towards the left. By now, all the forces from the right toe tip are transferred to the right arm which starts its action of throwing, which is a *pull-through* with the right elbow leading. The angle at the elbow is first shortened and then lengthened as the javelin is released high above the right shoulder (Fig. 8). By this time, the hand lifts the javelin and the body weight is in the process of going over the left foot.

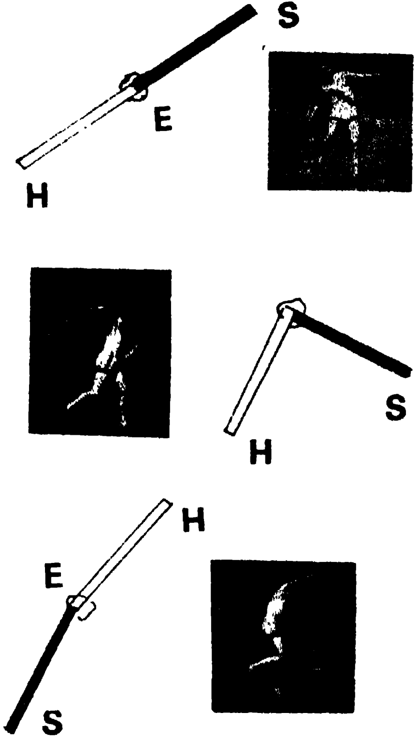
As in putting the shot and discus throw, the left leg which has been thrown well forward will now act as a " brace ". This action will check the forward momentum of the body, and all the forces will transfer upwards to the upper body and the javelin itself. With the body weight now up on the left leg, the javelin leaves the hand at probably between 35 to 40 degrees angle to the ground; the final impetus is provided by a wrist snap as the javelin is released.

THE FOLLOW THROUGH: The last forward step with the right leg is the " follow through " (count 5). If the thrower comes into the proper throwing position and has been able to impart his force to the javelin in a 'ballistic' effort, this force will carry his body forward towards the javelin arc. This " follow through " action is a natural part of the whole event.

A point to remember: at all times check that the flight path of the javelin throughout the approach run, throw and flight is exactly along the line of the body action itself.

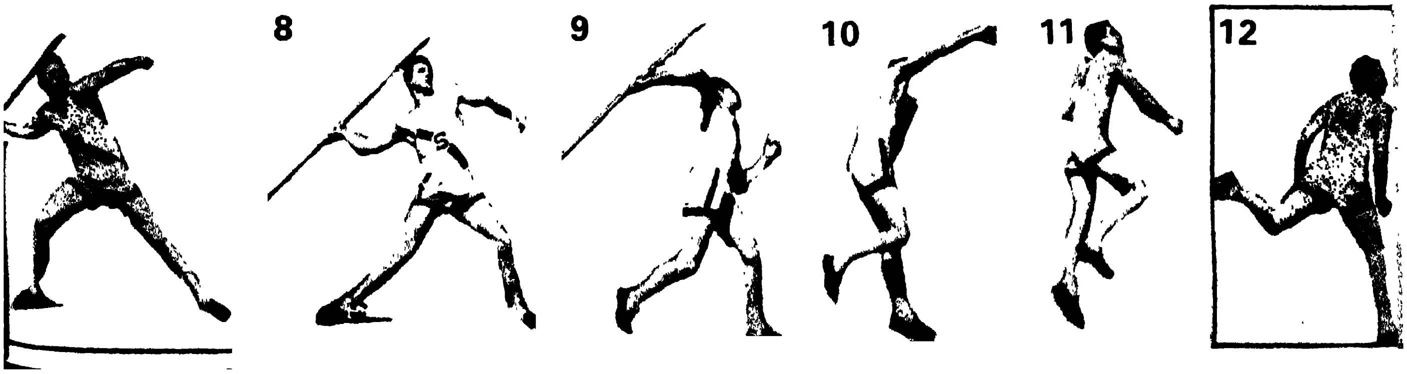
Fig. 8

H = Hand ; E = Elbow ; S = Shoulder



Irrespective of what has been written above, the most satisfactory way of learning correct javelin delivery is from a *standing position* (Fig. 11). After this phase has been mastered, the

Fig. 7 A JAVELIN SEQUENCE: (1) After running the desired distance, the thrower approaches mark. (2) As the left foot is near-about check mark 3, the spear is taken back, left arm relaxed and synchronised forward with right leg. (3) As the thrower moves forward with easy strides, the javelin goes back completely; right foot completes the step on count 1 toes pointing inwards to the right. (4) With a relaxed position, weight shifted back, the left leg lands, the foot pointing inwards to the right (count 2); the thrower prepares himself for the " cross-over " step with the right leg. (5) The " heart " of the javelin throw, the " cross-over " step It is executed with left hip facing forward and right shoulder back and down. (The right leg after execution of the " cross-over " step is in the process of landing) (6) On count 3, the right leg completes the "cross-over" step, foot landing almost at right angles to the direction of the throw. Throwing arm is not fully extended. The left arm is held forward for balance. (7) In the process of a perfect landing position after " cross-over " step. Left leg still in the air, right foot flat on the ground. (8) As soon as the left leg lands on count 4, the throw begins. Both feet are on the ground but completely apart. (9) Right hip comes into the throw, pulling right shoulder forward with elbow lead (10) After giving the final wrist snap, the throw is completed at the height of the arm. The body is in the process of going up and over the left foot. (11) The beginning of a perfect " follow through ". Eyes focussed on the flight of the javelin. (12) On count 5, the " follow through " with the right leg straight ahead is complete, left leg hanging for balance



athlete can begin to use forward momentum to assist him in exerting additional force on the javelin. The throwing position that is being learnt and practised from the standing position should be identical to the throwing position at the end of the approach run.

The question of attitude

The Finns believe that throwers must take chances; consistency of performance does not count for much, since it is the *one big throw* which wins the gold medal. They expect their throwers to be erratic and, more importantly, optimistic. If five of the six throws happen to be missed, the athlete must still go back to his mark and let fly, win or lose.

The epitome of the above attitude, in a way, was Miklos Nemeth of Hungary who won the gold last year at the Montreal Games. Yet, everybody had given up hope for him. Way back in 1967, at the age of 20, he was ranked second in the world. However, he didn't fulfil his promise. He failed to qualify in Mexico (1968); finished a weak seventh at Munich (1972), and in 1974 again came seventh at Rome in the European Championships. He was named " the easy-going Miki ". But at Montreal, in the very first round, " the easy-going Miki " unleashed an incredible " la Beamon " — 94·58 metres (310 ft 4 in) — shattering the Olympic record by over four metres and the world record by 50 centimetres. His second and third attempts were fouls, the remaining three falling almost ten metres short, yet, that one big throw won the Olympic gold.

Miklos Nemeth notwithstanding, most coaches agree that in competition, the first throw should usually not be one for maximum distance. It is felt, a relaxed safe throw often " grooves " the athlete for maximum effort on succeeding throws.

Fig. 9 Miklos Nemeth: from " easy-going Miki " to world champion

Training

At the outset, it must be made clear that the athlete must never begin his practice sessions unless he is properly warmed-up. The athlete must also remain relaxed and free from tension.

Once the grip has been chosen, the learner should immediately begin to develop control of the javelin itself. This is best done by throwing the javelin initially to a distance of 10 to 15 metres (not on the track or jumping arenas!). These throws should be relaxed and delivered with emphasis on control and accuracy. When the flight pattern has been controlled, the learner should run a short distance and continue to throw. At this stage, there should be no feeling of acting under pressure, as the purpose of the activity is to develop a touch, a feel, a sense which often require several days and hundreds of repetitions.

After a sense of control has been developed, the learner should begin to extend his throws to 20, 25 and 30 metres. These throws are to be made from a standing position (Fig. 11), with the flight (trajectory) of the throws at about 35 to 40 degrees angle. In all these 'standing throw'

TRAINING SCHEDULE

Monday: Jog 400 metres and further warm-up with body bending and stretching exercises followed by lead-up weight training exercises. Two lengths of 50 metres for "cross-over" step exercise (Fig. 10). Throw javelin from a standing position several times. Measure check marks and run through several times without actual javelin delivery. Take 4/5 throws for form, followed by further 5/6 relatively good throws for distance. Work with sprinters for a while and jog down.

Tuesday: Warm up as on Monday. Make several short throws into the ground. Run through the approach several times and work for 20 minutes on form followed by 12 throws with good effort. End up with three lengths of 50 metres training for "cross-over" step followed by 4 dashes of 30-metre sprints. Close down with a jog of 400 metres.

Wednesday: Jog 800 metres and warm-up as on Monday followed by weight training exercises. Work with sprinters for 20 minutes. Run through (fast) all the steps from the starting point and try to get into *position for throwing* (Fig. 11) with greater speed — 10 times. After rest, take 4 lengths of 50 metres or 2 lengths of 100 metres for " cross-over " step exercise. If not very tired, after rest, take up six hard throws for distance.

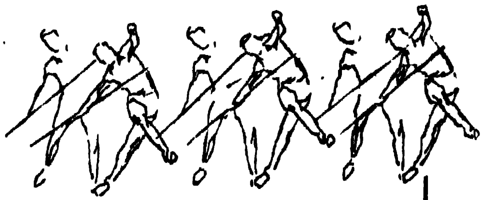


Fig. 10

Thursday: Jog and warm-up as on Monday. Go over 4/5 hurdles (low) half a dozen times for standardising the strides. Throw eight to 10 times with full run but at three-quarter final effort. Rest. Take four lengths of 50 metres for " cross-over " step exercise with weighted belt. End with jog.

Friday: Rest.

Saturday: Competition. If there is no competition, try to throw for distance at least six times.

(Note: Training with heavier implements than the standard ones is a part of the weight training programme.)

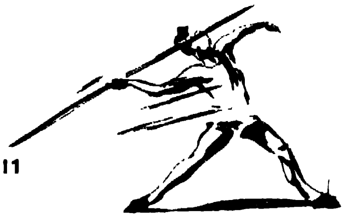


Fig 11

European training methods

[illegible]

practices, and even with a run, the energy must be expended into the javelin, making sure that there is minimum of flutter in the javelin in flight.

As we had stated in our discussion on the discus (Science Today, May 1977), it is common knowledge that a skill learned at one rate of speed is difficult to maintain at another rate of speed. Thus, javelin throwing from a 'standing' position and from an 'approach run' are two distinct motor skills. This is why the learners should introduce themselves to the 'run and throw' as soon as they are able to control the flight of the javelin.

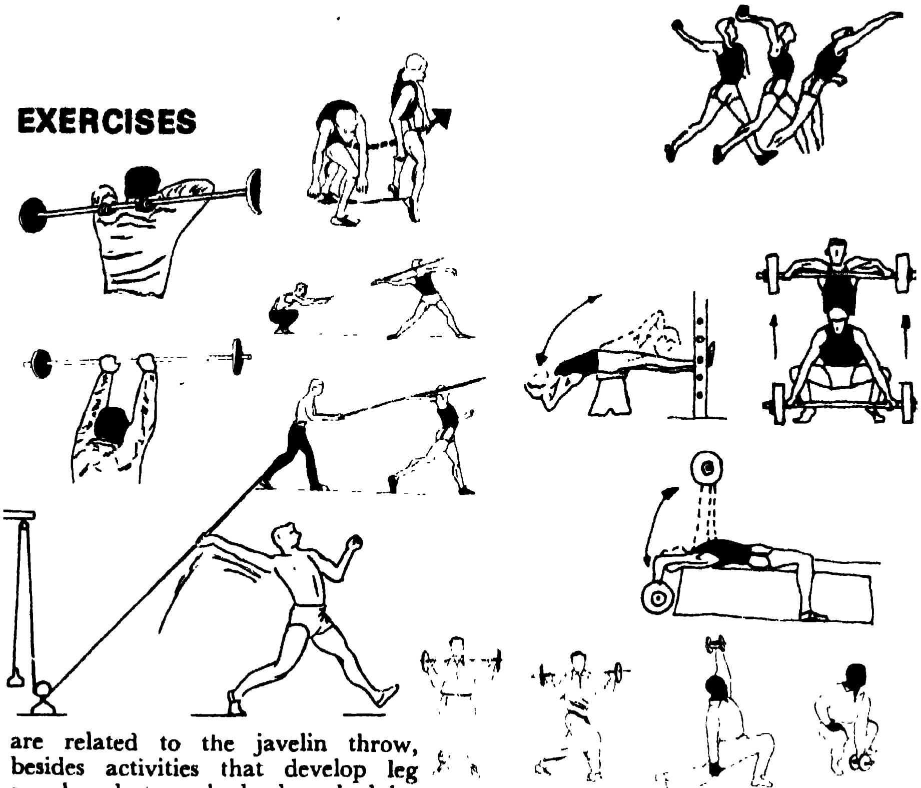
Once the check marks have been established and the "cross-over" step learnt, the athlete is ready for serious practice.

Success in the javelin depends to a large extent upon speed and strength and their application from a position of balance. To attain these essential factors, hundreds of approach runs with bounding strides, cross steps and turns of the body are to be gone through. Once one has achieved some measure of proportion and power, come the years of perfecting technique.

Good javelin throwing also requires general body development and the training programme must include general conditioning. Pre-season work must include exercises which are related to the javelin throw, besides activities that develop leg speed and strength, back and abdominal muscles as well as arm and shoulder girdle strength (see diagrams above).

"Margitta Gummel (at one time world record holder in shot putt and gold and silver medallist 1968 Mexico and 1972 Munich Games), for instance, trained with men's shot until 4 days before the contest in Mexico; [illegible]

EXERCISES



Usually, to a track enthusiast, swimming is taboo. However, considering the overall body conditioning and arm exercises involved in swimming (over-arm, breast stroke, back stroke, etc), it should actually be excellent for events like the javelin. Kenneth Doherty once remarked that, for many years he had noted with great interest that varsity swimmers who attempted the javelin event after the swimming season was over were able to produce amazingly consistent good performances.

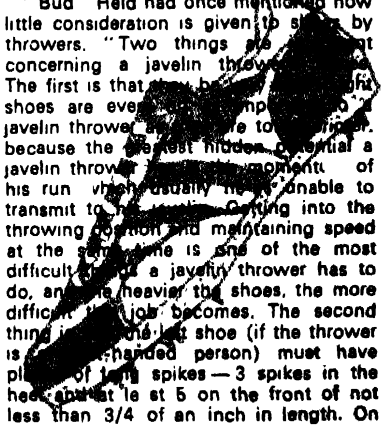
Wood-chopping is also a very good exercise. In fact, the Finns attribute the fact of there being so many first class javelin throwers in Finland to their ancestral heritage of wood-chopping and catching fish with spear. No doubt methodical wood-chopping is a direct adjunct to javelin throwing as the action is very similar to throwing. It further develops those back and abdominal muscles directly involved in javelin throws. But, then, one has to find the opportunity to do so!

"Bud" Held has emphasised that throwing the javelin is the best training exercise there is for javelin throwers. A thrower should never go for much easy throwing for the sake of form. He suggests that it is better to throw for distance twice a week than to throw for form five times a week. He further says, "In throwing for distance in practice, a thrower should learn to get excited, just as he does during competition. If he does not learn to practice with a feeling of excitement he will not be able to use this feeling properly during the competition".

Part of the warm-up should consist of running 100 metres doing nothing but the fast practice of "cross-over" step and that, too, not once but several times (Fig. 10). This mastering of the "cross-over" step is the key to success. It must become second nature to the thrower so that he shall not have to think of it during training or competition.

SHOES

The run-up area for the javelin throw is quite different from the circle for the shot putt and discus throw and the javelin thrower should select shoes which provide not only stability but also add to the efficiency of throwing. Some prefer regular running shoes with two spikes in the heel Such shoes provide more traction and are useful even on soft or wet runways.



"Bud" Held had once mentioned how little consideration is given to s[illegible] by throwers. "Two things [illegible] concerning a javelin thr[illegible] The first is that [illegible] shoes are eve[illegible] javelin throwe[illegible] because the [illegible] potential a javelin thrower [illegible] momentum of his run [illegible] unable to transmit to [illegible] Getting into the throwing [illegible] maintaining speed at the [illegible] is one of the most difficult [illegible] a javelin thrower has to do, and the heavier the shoes, the more diffic[illegible] job becomes. The second thing [illegible] shoe (if the thrower is [illegible]-handed person) must have pl[illegible] of [illegible] spikes — 3 spikes in the he[illegible] le st 5 on the front of not less than 3/4 of an inch in length. On soft grass, even longer spikes are desirable. If the left foot slips, even by so much as two inches, the throw will be considerably impaired."

learn while you play–9

B. D. KELKAR
A. V. DESHINGKAR

How long is a metre? You would think it's a silly question; you would say, " Why, it's marked on any scale or tape measure! " But, did you ever wonder how that particular measure marked on the scale or tape came to be? Well, the story of the metre goes nearly 300 years back in time: in 1670, Gabriel Mouton, who was vicar of St. Paul's Church in Lyons, France, proposed the metre as the basic unit of length — as a fraction of the great circle of the Earth. More than 100 years passed before anybody would consider Mouton's metre. Then, in 1795, France adopted the decimal system of measurement and the *mètre* was taken to be *supposedly* one ten-millionth of the distance from the north pole to the equator, along the meridian passing near Dunkirk, Paris and Barcelona.

You noted the word " supposedly "? Scientists today are so particular about accuracy that they have found another definition of the metre: it is 1,650,763·73 wave lengths in vacuum of the orange-red line of the spectrum of Krypton 86 (see Fig. 1, below).

Have you guessed why we have talked about the metre at such length? The reason lies in that term "wave length", because it implies a vibration, a movement up-and-down, or to-and-fro, or in other words, " oscillations ". Among all types of motions, the oscillatory motion is perhaps the most important. Every particle (consisting of atoms which comprise protons, neutrons and electrons) vibrates. The light, sound and electro-magnetic waves have vibrations of different types which make them behave differently. The waters in the great seas vibrate with particular amplitude and frequency.

You know what frequency, is, don't you? It's the number of to-and-fro movements every second. And amplitude? It's the extent of displacement from the original position. Fig. 2 gives a clear idea.

Let's now go on to the most common example of oscillatory motion we had studied before (SCIENCE TODAY, January 1977) — the swing of a pendulum. We know now — as Galileo had ascertained with his pulse beat (and we have the stop-watch!) — that it takes about the same time for a narrow swing as for a wide one! This phenomenon — equal times for all amplitudes — has an elaborate name — ' isochronous ", a Greek word meaning " equal in time ". It is found that all the repeating isochronous vibrations have the same type of motion with the same *shape* of time-graph. This is known as a "sine curve". We call such motion " simple harmonic motion " (SHM).

Let's make a simple device to understand this. The device is shown in Fig. 3. Attach a sketch pen to the pendulum bob and set the pendulum swinging. Now, as you slowly (and with uniform speed) pull the paper from the roll, the swinging sketch pen will draw a graph. This is the sine curve.

We have seen that a pendulum moves with SHM for all amplitudes. Similarly, a load hung from a spring bounces up and down with SHM amplitude over a wide range (Fig. 4). A coiled spring with a load is an elastic system; flexible beams, stretchable wires, twistable rods — all fall within this category. And they all obey Hooke's Law. Let's prepare a simple experimental set-up (Fig. 5). We shall need a coiled spring used inside ball-point pens, a cardboard pan and some weights, say, of 5, 10, 20 and 50 grams. Turn the ends of the spring into hooks with a pair of pliers, hang one end from a nail on a wooden board and from the other end, suspend the cardboard pan. Fix a scale on the board vertically. Place different weights on the pan and mark the spring's extension against the scale. *The increase in the length of the spring will be proportional to the load.* And that is known as Hooke's Law, discovered by Robert Hooke three

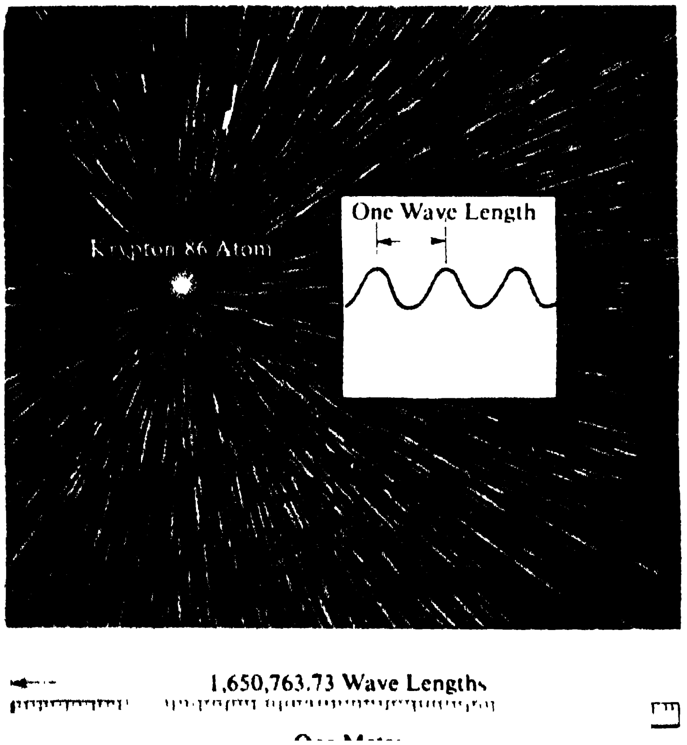


Fig. 1

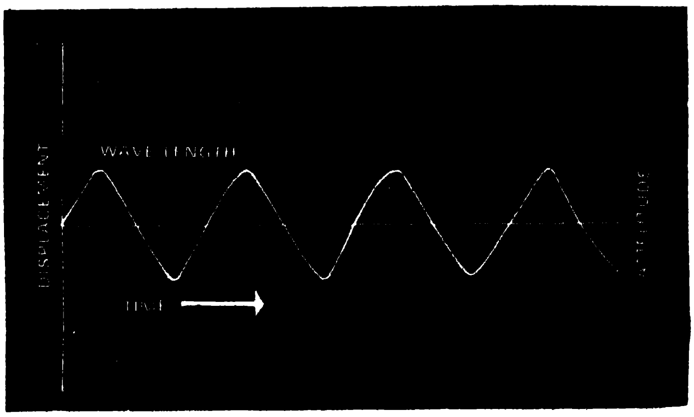


Fig. 2

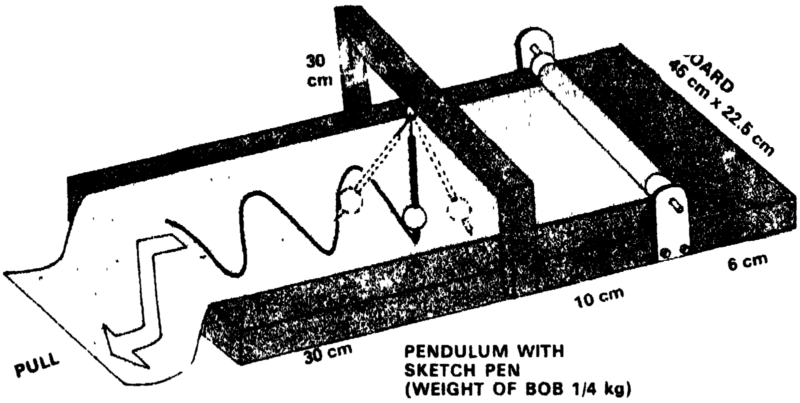


Fig. 3

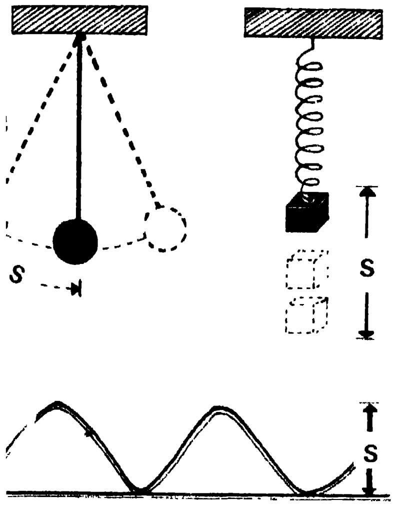
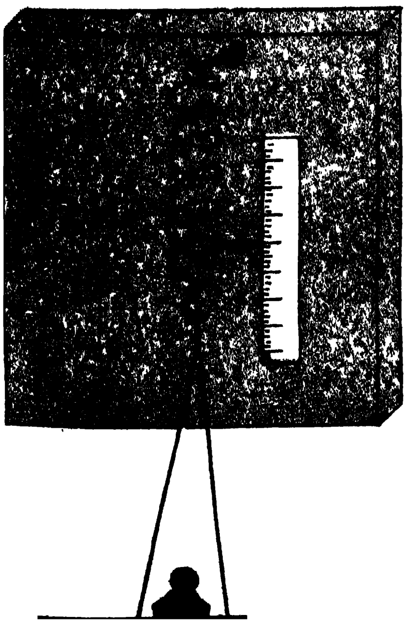


Fig. 4

centuries ago. You can easily notice that the load required for each centimetre expansion in the spring will be constant for the elastic range of the spring and is known as "spring constant-K". It can be written as

$$\frac{\text{Load (or stress)}}{\text{Elongation (or strain)}} = \text{Constant.}$$

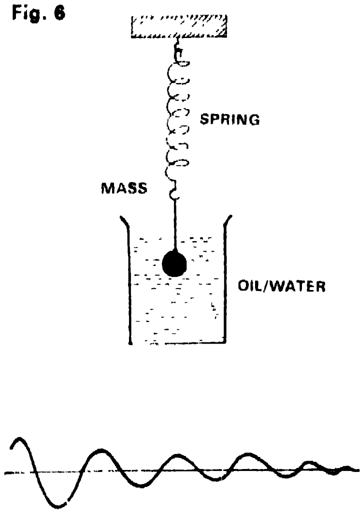
Fig. 5



Suppose we pull the spring and let it go! The spring will oscillate up and down freely. The vibrations will continue for several cycles. (This is known as free vibrations with spring-mass system.) If we plot the positions of the pan-end of the spring at different points of time, the graph will resemble a sine curve for several cycles. But, then, the resistance of air and the internal resistance of the spring will gradually overcome the oscillations and the graph will show a gradual decrease in amplitude (Fig. 6). This is known as *damping*. Take a tin filled with water and sink the mass into it. You will find the oscillations are slowing down rapidly. If, instead of water, we use some thick oil (say, lubricating oil), the oscillations will die down much more rapidly.

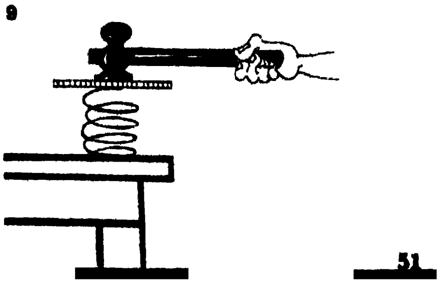
Figures 7 and 8 show two simple toys you can fabricate using the principle of the spring-mass system.

Fig. 6



If you walk about a car repairing workshop (or its backyard), you might come across a piece of thrown-away coiled spring generally used as a shock absorber in cars. Bring it home, place it on a table and place a hardboard on top of it. Now, first bang the table with a hammer and then hit the top of the hardboard on the spring (Fig. 9). Which blow felt harder at the grip of the hammer? The answer is obvious, isn't it? The spring got compressed by the blow and, therefore, offered less resistance. Now you know how springs

Fig. 9



NODDING JOKER

Take a spherical wooden ball and glue facial features cut out from cardboard (or paint them on). Fix a spring to it with a nail. Fix the other end of the spring on a longer cylindrical piece of wood; you can "dress up" this piece to resemble a human torso. The joker will nod his head with the slightest jerk given to it.

Fig. 7

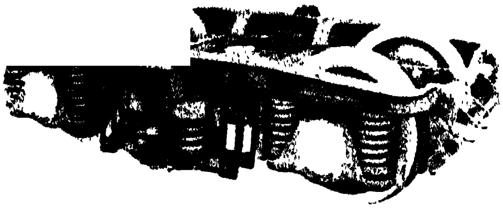
FLYING BIRD

Prepare the body and head of a bird with clay or plaster of Paris. While you are making the body, insert four springs — one each for the head and the tail and two for the wings; also insert a hook for tying a string. Let the model dry. Make the wings and tail using feathers and attach these to the respective free ends of the springs. Tie a string to the hook and holding the other end, give it a jerk. The wings, head and tail will start oscillating, simulating the flight of a real bird.

Fig. 8

act as shock-absorbers in the wheels and axle-mountings in vehicles. On uneven surfaces, the wheels receive jerks or shocks which get transferred to the flat or coiled springs (Fig. 10). The springs get compressed and, as a result, the chassis or body of the vehicles receive much less jerk.

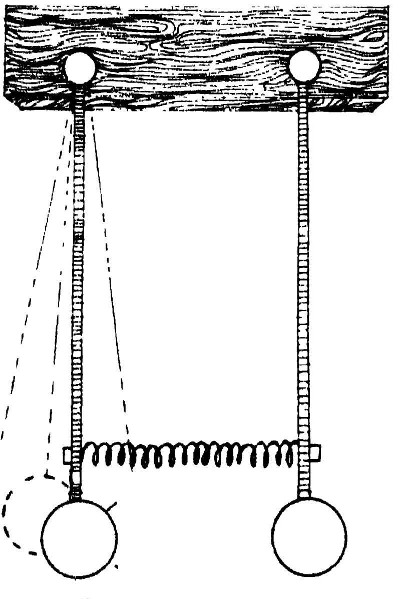
Fig. 10



Twin-pendulum

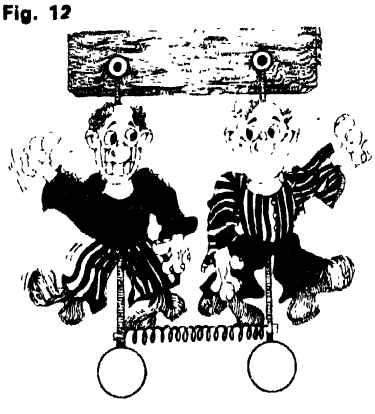
We have already seen how the oscillations of a simple pendulum are periodic like a spring-mass system. Let's now prepare an interesting set-up of a " twin-pendulum " (Fig. 11). We need just two metal bobs (or big wooden spheres) of about 100/150 grams each, two pieces of galvanised wire (3 mm size) about 30 cm long and a thin spring about 3 to 4 cm long. Turn one end of the wires into hooks and pass the other end through holes made in each sphere; you get two pendulums; see that the lengths are the same. Now, hang the pendulums from two nails on a wooden board. Bend each end of the spring into a hook and, then, attach it to the two pendulum wires; the spring must be slightly *taut*.

Fig. 11



What happens if you oscillate one of the pendulums? Strangely, the two pendulums will oscillate *alternately*. Can you work out the reason behind this? It's quite simple really: the " interlinking " spring absorbs the energy during every oscillation of a pendulum and feeds part of it to the other one. Thus, the swinging energy of one is passed to the other through the spring. The cycle is repeated until all the energy is dissipated away due to friction at the hinges and, of course, due to air resistance. Just for fun, cut out two figures from cardboard and attach them to the pendulum wires (Fig. 12).

Fig. 12

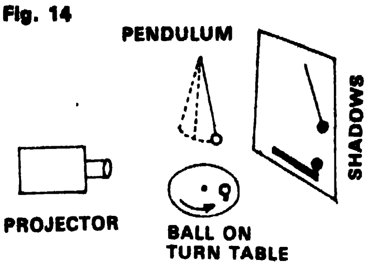


How about some more experiments with vibrations and oscillations? Two such projects are shown in Figs. 14 and 15. If you are electronically-minded, you could work out some toys with small electric motors. Two such models are shown in Figs. 13 and 16.

We have seen how vibrations are a part of our daily life. In many cases, particularly in machinery, vibrations have to be eliminated by proper balancing of the components and by introducing *damping*. But, then, vibrations are *forced* on certain machines like grading sieves or vibrating screens, used in grading sugar, seeds, grains, etc.

We also know, when a body vibrates, it sets the air around it vibrating, too, and produces sound. Next month, we move on to the world of ' sound '. Remember, sound is essentially *vibrations* produced in an elastic medium!

Fig. 14



MATCHING SHADOWS

We shall need a turn-table (of a gramophone or can make one with a suitably mounted toy electric motor). A wooden ball is fixed on the turn-table. Suspend another ball of the same size from a string. We shall need a light source to project shadows on a white screen or wall. Start the turn-table and, also, let the pendulum swing with an amplitude equal to the turn-table's diameter. Will the shadows of the two balls coincide?

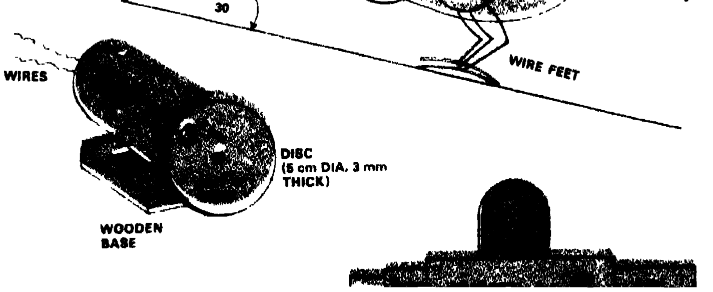
DANCING SPARROW

Take a toy electrical motor and mount it on a wooden base. Fix an aluminium disc (using Araldite) to the motor shaft. Drill a hole 2 cm away from the centre of the disc and fit in a bolt and nut in the hole. Use a dry cell battery and start the motor. You will see that a centrifugal force is produced due to the bolt fixed on the disc and this causes the wooden base to *vibrate*; actually, the base block will move hither and thither due to these vibrations caused by unbalanced force due to the disc's rotation.

Now, cut the outline of a sparrow from a 2·5 cm-thick thermocole sheet. Cut out a hole in the sparrow's body to fit the motor; fix it with Araldite. Now mount a disc with a nut-and-bolt as described earlier and use 3 mm-diameter wire to prepare the sparrow's feet. See that the sparrow balances well on the wire-feet (incline the body of the sparrow through 30° to the ground). Also, remember that the motor has to be placed at the centre-of-gravity of the sparrow (this position can be found by trial and error).

Start the motor by connecting with a dry cell battery. How the sparrow will dance!

Fig. 13



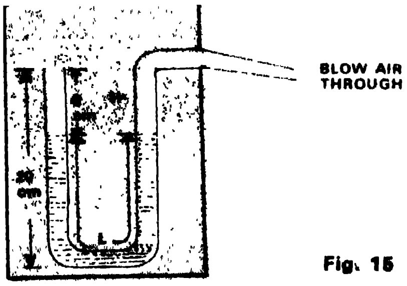


Fig. 15

OSCILLATING WATER COLUMN

Take a U-tube from the chemistry lab and pour some coloured water into it. If you blow in air from one end, the water column will begin to oscillate until the energy of oscillation is dissipated away in friction. of water with the glass and also the pressure of air (which is equal at both ends). Vary the free air column (H) in height and measure the number of oscillations in one second. You will find that the number of oscillations per second can be increased by decreasing the length (L) of water column and vice versa.

BIFILAR & TRIFILAR SUSPENSION

This is an experiment with torsional vibrations of a twisted wire. Take two or three 2 mm-diameter long wires (50 cm) and a heavy steel disc, about 1 cm thick and 20 cm in diameter. Attach the lower ends of the wires to the disc by soldering or brazing (in a tinsmith's shop). Attach the upper ends of the wires to the ceiling. Vary the length of the wires and measure the number of oscillations per second (by i itially twisting the disc ends of the wires and then releasing). You will find that as the length of the wires decreases, the number of oscillations per second will go on increasing.

In this case, the [illegible] behaviour of the wires in twisting makes the suspension to vibrate.

PAIN RELIEVER

We use the same principle of a 'vibrator' used in the dancing sparrow. This time, place the motor and disc (with nut and bolt) *inside* a torch body; use proper packing so that the motor fits in properly. Place a single dry cell battery inside, too. On the front side of the torch, fix a wooden peg. As you put " on " the switch, the torch will vibrate. Place the wooden peg against your body and you can feel a soothing " massaging " effect.

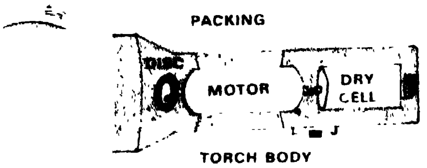


Fig. 16

PUZZLE TIME

● Magic rotor

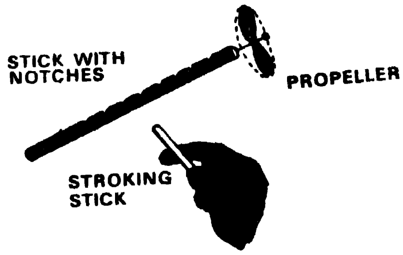
R. W. Leonard, the inventor of this toy, had named it " magic windmill ". And, believe it or not, he wrote about it in one of the most prestigious journals, the *American Journal of Physics*, and that, too, in 1937. Ever since Leonard's paper appeared, scores of physicists and others have taken up the puzzle behind its working, but, it seems, nobody has come out with *the* answer.

The toy is simple. All you need is a small rotor blade and two sticks — one with notches cut into it; the other stick is used for stroking the notches. Pin in the propeller at one end of the notched stick. Hold the notched stick with the forefinger near the far end and the thumb on the near side. Run the other stick back and forth over the notches.

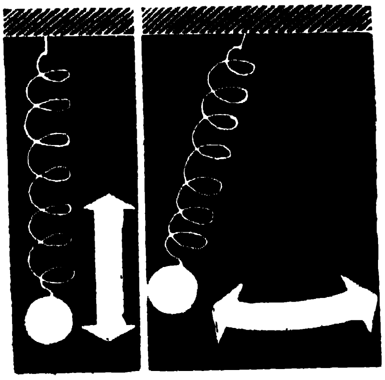
While stroking, let the forefinger press against the notched stick. The propeller will turn in one direction. Now, as you continue stroking, loosen the forefinger and press the thumb against the notched stick. What happens now? The propeller will turn in the *opposite direction*?

You can actually turn it into a magic show *by shifting from the forefinger to the thumb* (while everybody's eyes are focussed on the rotor) and making the rotor change direction alternately.

Let's tell you, while many have been able to figure out why the rotor turns at all (can you work it out?), many are still baffled by the mystery of why the *change of finger* should change its direction of spin.



● Spring pendulum

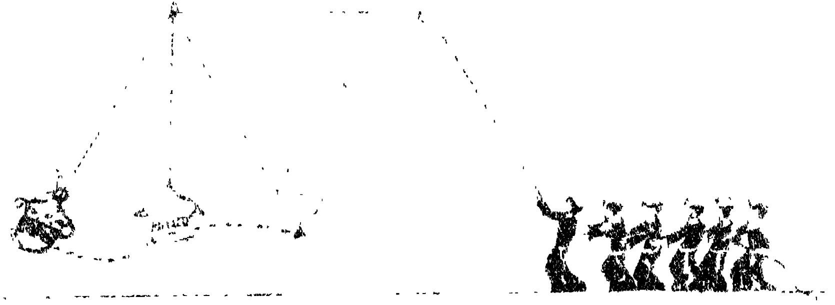


Did you know, if you choose the correct spring and bob, a vertically swinging spring pendulum will also swing *horizontally*? A vertical pull will start vertical oscillations in the pendulum, but as soon as the vertical motion comes to a stop, the bob will begin swinging *sideways*. Then, after the horizontal swing dies away, the *vertical* oscillation begins again. This will go on as long as there's energy left in the system.

Now, why does it happen?

[*Clue* : Coupled harmonic motion and sympathetic oscillation.]

● A Spanish puzzle



A famous place of pilgrimage in Spain is the shrine of St. James in Santiago de Campostella. Here, the faithful come to burn incense, in a large brazier hung from the ceiling of the church. To make the charcoal in the brazier burn well, the brazier is swung by the priests.

First, the brazier is swung with a small amplitude. Then, six men pull on a rope until the brazier swings through 180°.

Now, there's a curious element here: the six priests pull at the rope by *shortening* it by about a metre each time it passes through the vertical; when the brazier reaches its maximum height, they *release* a metre of the rope.

Can you work out why shortening and lengthening of the rope increases the amplitude of the swing?

[The three problems presented here are adapted from a remarkable compilation *The Flying Circus of Physics* by Jearl Walker.]

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Mechanics and school physics

MECHANICS by S. R. Shankara Narayana and K. L. Chopra, Sultan Chand and Sons, New Delhi, 1976, Rs. 18

SECONDARY SCHOOL PHYSICS by N. K. Sehgal, K. L. Chopra and D. L. Sehgal, Sultan Chand and Sons, New Delhi, 1975, Rs. 3·50

Though the first book is titled *Mechanics*, principles of statics in general and their applications to the statics of structures, etc are not discussed. And nor are equilibrium of fluids and fluid motion. What are included, and treated carefully, are kinematics and dynamics of a particle, systems of particles and of rigid bodies. The reviewer sees no pedagogical reason why conservation laws of momentum, angular momentum and energy could not have been discussed in the earlier chapters. This would have avoided unnecessary duplication. A shorter chapter on the genesis of conservation laws through symmetry principles would then be in logical order. Similarly, the discussion of inertial systems of reference and the rotating frames of reference could go well together.

Surprisingly, though scattering is discussed, scattering cross-sections are not even mentioned. Their inclusion would have enhanced the value from the point of view of atomic and nuclear physics. However, a careful treatment of the scattering phenomena from a laboratory frame of reference has been given.

In the chapter on rigid body motion, I feel the motion of the symmetrical top would have brought out more significantly the importance of the use of Euler's equations rather than the two examples chosen.

The get-up is fairly good, except that bold face letters should have been used for vectors instead of those arrows and hats. In my opinion, the book is a very good and serious attempt.

Secondary School Physics is actually two text-books for Classes IX and X. It is written according to the (New) Secondary School Syllabus prescribed by the Central Board of Secondary Education, New Delhi. A good attempt is made to present the material in a fairly interesting manner by including many, though poorly drawn, pictures and diagrams.

Although sufficient care must have been taken by the authors to make the book free of mistakes, it contains, besides a few typographical errors, many erroneous statements. The very first sentence in " The fish's eye view " is wrong, while the related statement at the top of Fig. 12·9 is correct. On pages 66–67 (Class X), confusion about magnetic vectors H and B is made worse by statements like if the conductor (why conductor only?) is present in the medium, etc. The constant μ_0 in the Coulomb's Law for poles appears in the wrong place due to the mistaken impression that μ_0 corresponds to ε_0. In treating potential difference and EMF, no use is made of the energy concept; and why does the deflection of a gold-leaf electroscope indicate voltage (PD) rather than charge?

R. V. KAMATH

Hypnotism and hysteria

HYPNOTISM, HYSTERIA AND EPILEPSY — an historical synthesis by E. M. Thornton, William Heinemann, Medical Books Ltd, London, 1976, 205 pp, Rs. 95 (£5·95 net)

In an ambitious venture, the author has probed the historical leitmotif linking hypnotism, hysteria and epilepsy. Sir Wilder Penfield, celebrated neurosurgeon and author, earlier wrote several books on the historical aspects of epilepsy. This book follows the same tradition and provides an interesting insight into the origins of epilepsy. From the time Mesmer introduced hypnotism to clinicians and the lay public, medical enthusiasm for hypnotism has waxed and waned. Although hypnotism originated in France, it eventually fell into disrepute there. The study of hypnotism, which reached its zenith at the time of Charcot, was later almost completely abandoned as a scientific discipline. Readers, who are familiar with *The Story of San Michele* by Axel Munthe and with the vivid descriptions of Charcot's clinic, will understand the criticism and distaste for hypnotism that prevailed in some circles at that time. The author describes Prof. Bernheim's challenge to Charcot and his hypothesis that hypnotism is identical to natural sleep. In the light of current evidence on sleep mechanisms, his theories have proved fallacious.

More detailed information on animal experiments in hypnotism, together with an in-depth analysis of the role of hypnosis in therapy today, would have considerably increased the value of the book and served to link past history with the present-day medical scene. The book is anecdotal, well illustrated and has comprehensive author and subject indices. It is doubtful if the book will have a wide appeal for non-medical readers. And it is far too specialised to warrant purchase at the quoted price, except for large libraries.

JOY DAVID

[Dr. (Mrs.) David is with the CIBA-GEIGY Research Centre, Bombay.]

Computer languages

A SHORT INTRODUCTION TO THE ART OF PROGRAMMING by Edsgar W. Dijkstra, Computer Society of India, Bombay, 1977, 68 pp, Rs. 12 (paperback), Rs. 16 (hardcover)

Contrary to what the title might suggest, the book primarily addresses people who already know a computer language. It tells them how to ensure that the programs they write are correct from the very beginning. And, in the process, an aesthetically pleasing programming style is also developed.

While the primary readership is made up of computer programmers, the first two chapters use almost no technical terminology. The first explains such basic concepts as algorithm, program and machine, using instructions for a housewife to peel potatoes for dinner as the central example! The second one, on programming languages and their implementation, is a good introduction to the working of a computer, using little more than the notation of high school algebra. The next two chapters lay the foundation for the examples to follow. The building of proofs of programs is discussed and a number of theorems are established for the purpose. The need for proofs of correctness of computer programs is gaining wider acceptance among those in the trade. The proof techniques explained here are applicable to a wide range of programs.

The rest of the book is a succession of examples solved through stepwise refinement, also popularly known as structured programming. The examples do not represent everyday programming problems to most programmers.

The book is thought-provoking for practising computer programmers

(Contd. on p. 57)

Why does thunder end with a growl?

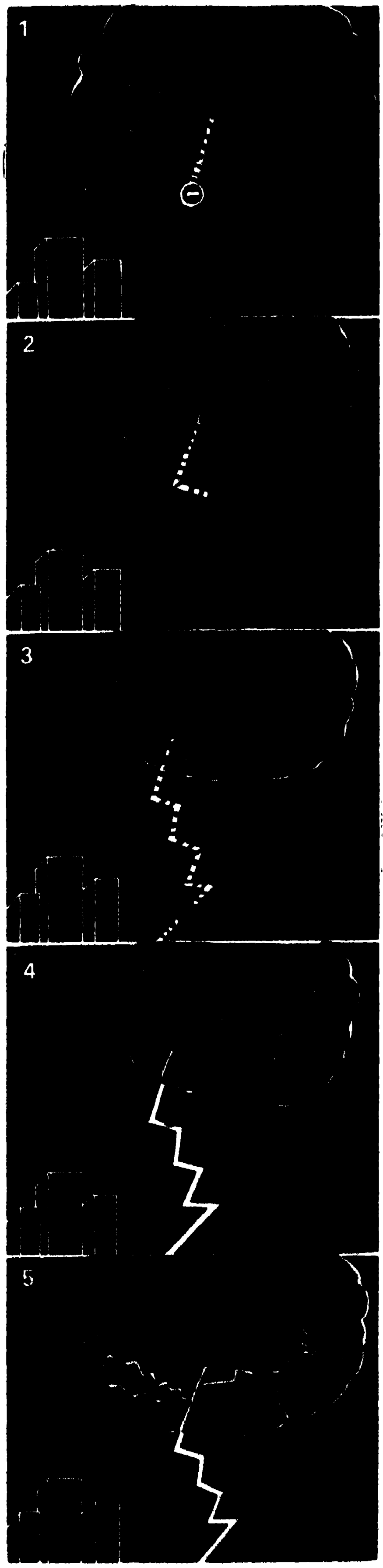
All of us are familiar with the relation between lightning and thunder. The initial flash of light is followed by the delayed burst of slower-moving sound. But notice how the thunder ends. Not with a bang, but a grumble—a slowly tapering, protracted growl. Why so?

Since the answer isn't in the textbook, after thinking about the question a little, our answer will most likely be that this effect is due to the many echoes of the initial burst as the sound bounces off nearby and distant hills, buildings and trees. By the same reasoning, a fisherman, caught out at sea during a storm, should hear only a sharp crack following the lightning stroke, without the protracted rumbles.

But fishermen and sailors do hear much the same sound of thunder as we do, complete with its rolling finale. So we move on to another conjecture, that each lightning bolt is followed by *smaller* strokes which give rise to corresponding acoustical after-effects. In that case, why don't we see those secondary flashes? Well, they could occur inside the dark cloud, invisible to an observer down on earth. According to this theory, then, invisible lightning strokes are postulated to explain the persistence of thunder. How valid is this explanation?

Let us examine the relation between lightning and thunder a little more closely. One would have thought that in this age of pinched plasmas and charmed quarks, the subject of lightning would, by now, be cut, dried, and tied. It remains, nonetheless, one of the least understood natural phenomena, with theories of lightning not having proceeded much beyond the descriptive stage albeit a fairly detailed and sophisticated description.

Measurements of the distribution of electric charge inside a rain cloud have shown that this distribution is highly non-uniform. The upper portions are positively charged, while the lower portions and the middle usually contain huge amounts of negative charge. Why and how this happens is one of the several problems which have remained unsolved. The release of the negative charge seems to be related to the process of condensation of water drops, which takes place at a sufficiently cool (that is, sufficiently high) altitude, usually at about five kilometres above the ground. Such large conglomerations of electric charge naturally give rise to strong electric fields between the bottom of the cloud and the earth, and within the cloud itself. For instance, just before a thunder storm, the potential difference between cloud and earth may reach as much as 300 million volts, which corresponds to an electric field of 600 volts per centimetre. Thus, there is a strong force on the electric charge sitting at the bottom of the cloud, impelling it towards the earth.



(Left) Fig. 1 Sequence of a lightning stroke — from stepped leaders to return stroke. Sequence 5 shows horizontal extension of a lightning bolt

Now, a lightning bolt is a sequence of many events in which the cloud discharges some of its negative charge. It begins with a tentative probe known as a stepped leader. When the electric field in some region finally gets strong enough to overcome the insulation of the moist air, electrons begin to shoot down along the field lines. Along their path, they collide with various molecules, ionising them in the process, and, having thus dissipated their energy, they come to rest in a millionth of a second, 50 to 100 metres down the line. Then follows a relatively long pause of about 50-millionths of a second, after which a new step is formed from the leading tip of the first one. This sequence is repeated until the stepped leader reaches the ground, leaving in its trail a zig-zag of ionised air — a path of relatively low resistance, in other words, a jagged conducting ribbon connecting earth and sky. A burst of current now floods down this path carrying, perhaps, 10,000 amperes, and travelling with a speed of 10,000 kilometres per second. This is known as the first return stroke. As any resistive wire would in similar circumstances, the air along the conducting tube is rapidly heated to a high temperature. Molecules in the path are ionised, stripped, and excited to incandescence, producing the flash of light. Such rapid heating of a gas must be accompanied by its rapid expansion. A shock wave explodes outwards from the thin axis — the burst of thunder (Fig. 1).

Some tens of millionths of a second later, a second leader retraces the original path, sometimes opening forth new branches, and this leader, too, is subsequently followed by a second return stroke, usually of lesser intensity. Most lightning flashes consist of a number of such stepped leaders, each accompanied by its return stroke. Some have been photographed with as many as 30 return strokes. Here, no doubt, we have an explanation of our original puzzle. There is no need to invoke unseen lightning. Each stroke must be responsible for one boom of the rumble. This is indeed a plausible explanation, so let us proceed to verify it by calculating the total time that such a sequence, of, say, ten strokes, will take. Assuming a length of five kilometres for the path, each leader should take approximately one-hundredth of a second. Ten leaders should account for about one-tenth of a second. Not very encouraging. What about the main strokes?

Travelling at 10,000 kilometres per second, ten of these shouldn't take up more than another few hundredths of a second. The whole sequence of events would be over in well under a second. So our newly found solution does not fit the fact of a rumble lasting 10 to 15 seconds. The passage of electrons down the crooked and narrow path is much too rapid. By contrast, a sound wave would take some 15 seconds to travel down the same length.

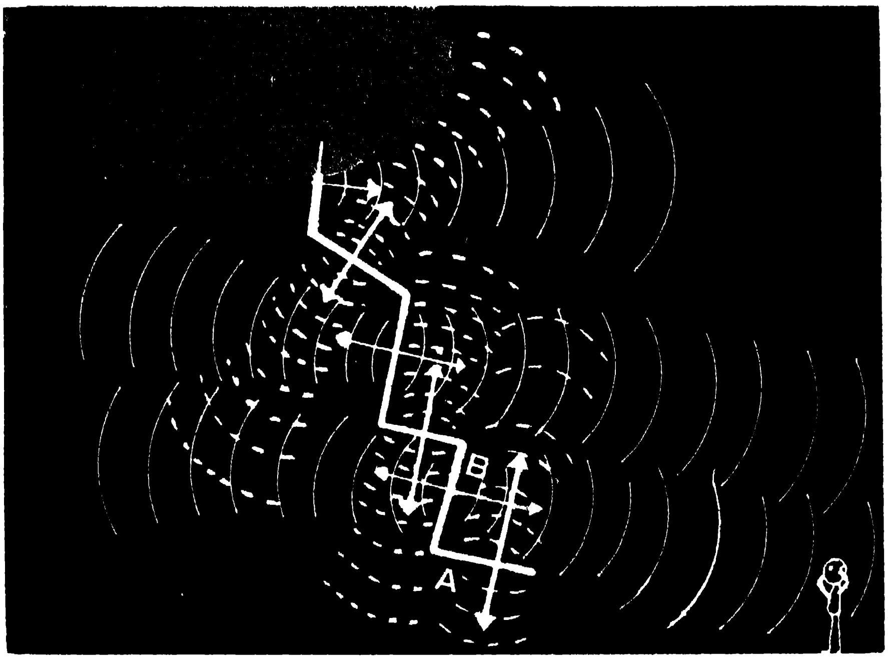


Fig. 2 Sound output from each lightning step travels perpendicular to its length. Though step A is along the observer's line of sight, the sound from step B will be heard louder though it is farther away

Now that the cat is out of the bag, all that remains is to arrange for its quick exit. Thunder, thus, is the acoustic output of an explosion which takes place along a continuous length of some five kilometres. If the listener is placed so that the nearest point of the explosion is one kilometre from him, the most distant point is still over five kilometres away. Even if the explosion is practically instantaneous, its acoustical emission will last 12 to 15 seconds for the listener, as sound from different spatial regions of the explosion successively reach his ear. According to this theory, the rumble should decrease in intensity from start to finish.

Observation proves otherwise. A later portion of the rumble is often louder than a preceding portion. Must we thus discard this explanation also?

It turns out that the emission of sound from each step of the exploding ribbon is strongly directional. Most of the sound output is sent out perpendicular to its length. Very little is emitted along its length (see Fig. 2). Now if we remember that the actual shape of the path is a three 1-dimensional zig-zag, it is easy to see that a nearby zig which is along the observer's line of sight, may emit less sound in his direction than a more distant zag which is oriented perpendicular to his line of sight. So the variation of loudness along the rumble also tells the observer the overall shape of the lightning stroke and how it is oriented with respect to him.

By placing an array of microphones over an extended region, and monitoring the sound output of a lightning bolt, it is possible to infer with considerable accuracy its largescale structure. It is possible thus to ' look ' at what is happening inside the dark cloud. It turns out that a lightning bolt often has a long horizontal portion extending within the cloud. This portion, which in a large cloud is of the order of 10 kilometres in length, is usually invisible. What we see then is less than half the story (though we hear all of it) or, if you wish, only the forked tongue of a luminous serpent.

VIVEK MONTEIRO

BOOKS *(Contd. from p. 55)*

and may improve their style. It can also prove useful as a joint textbook in introductory programming courses, together with a book or manual for the language used. At the very least, every teacher of programming must read it. Incidentally, Prof. Dijkstra's famous statement likening PL/1 — a programming language vigorously promoted by IBM — to a fatal disease appears on page 3 of this book.

H. V. SAHASRABUDHE

[Mr. Sahasrabudhe is Assistant Professor, Computer Centre, IIT, Kanpur.]

New maths

NEW MATHEMATICS (Book I to IV, 4 volumes) by C. V. Bhimashankaram and M. Imelda, Oriental Mudran, Bombay, 1976, Rs. 5·50 (Vol. I), Rs. 6·50 each (Vol. II to IV)

Much of the criticism of 'new math' is due to a lack of understanding on the part of the public and even some of the teachers. For successful adoption of a new mathematics programme, a school must ascertain where it would lead to and for what kind of students it was designed. The authors have made a sincere attempt to make this task easier at the elementary school level. Even untrained teachers and parents can follow the exposition of mathematical concepts.

Not much of the new mathematics in these books is really new. What is new is the emphasis on understanding the 'why' of mathematical operations and the attention given to mathematical structures.

A good strategy for teaching a mathematical concept must meet the demands of a proper teaching procedure and considerations of its applicability to the use of the concept later on. One of the first strategies the elementary school teacher must select is for the treatment of addition. Two different approaches are developed in the books. In the method on sets, addition is introduced by considering disjoint sets and their combination and by recording the number of objects in each. The treatment of this situation later on, using the symbolism and operations of sets, may be too much for many students, and is not at all essential at this level. On the other hand, the number line gives the relationship of numbers, the order, and is very useful in developing the properties of addition. It is also useful for the introduction of rational and real numbers and graphs at the secondary school level.

P. R. CHANDRASEKHAR

[Prof. Chandrasekhar teaches mathematics at Ramnarain Ruia College, Bombay.]

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TWO-WIRE IC INTERCOM

The two-wire intercom set described below will be very useful in offices or in homes. The intercom set, when not in use, does not draw any current; thus, it can be economically supplied from a single 9-volt battery. The provision of call tone, from either set, is the unique feature. Secondly, it requires only two interconnecting wires between the two sets for the call tone as well as two-way communication. The use of a single integrated circuit CA 3020 makes the construction of the unit very simple. Two loudspeakers, one in each set, are used for two-way communication. Each one of them, in turn, is used as a microphone.

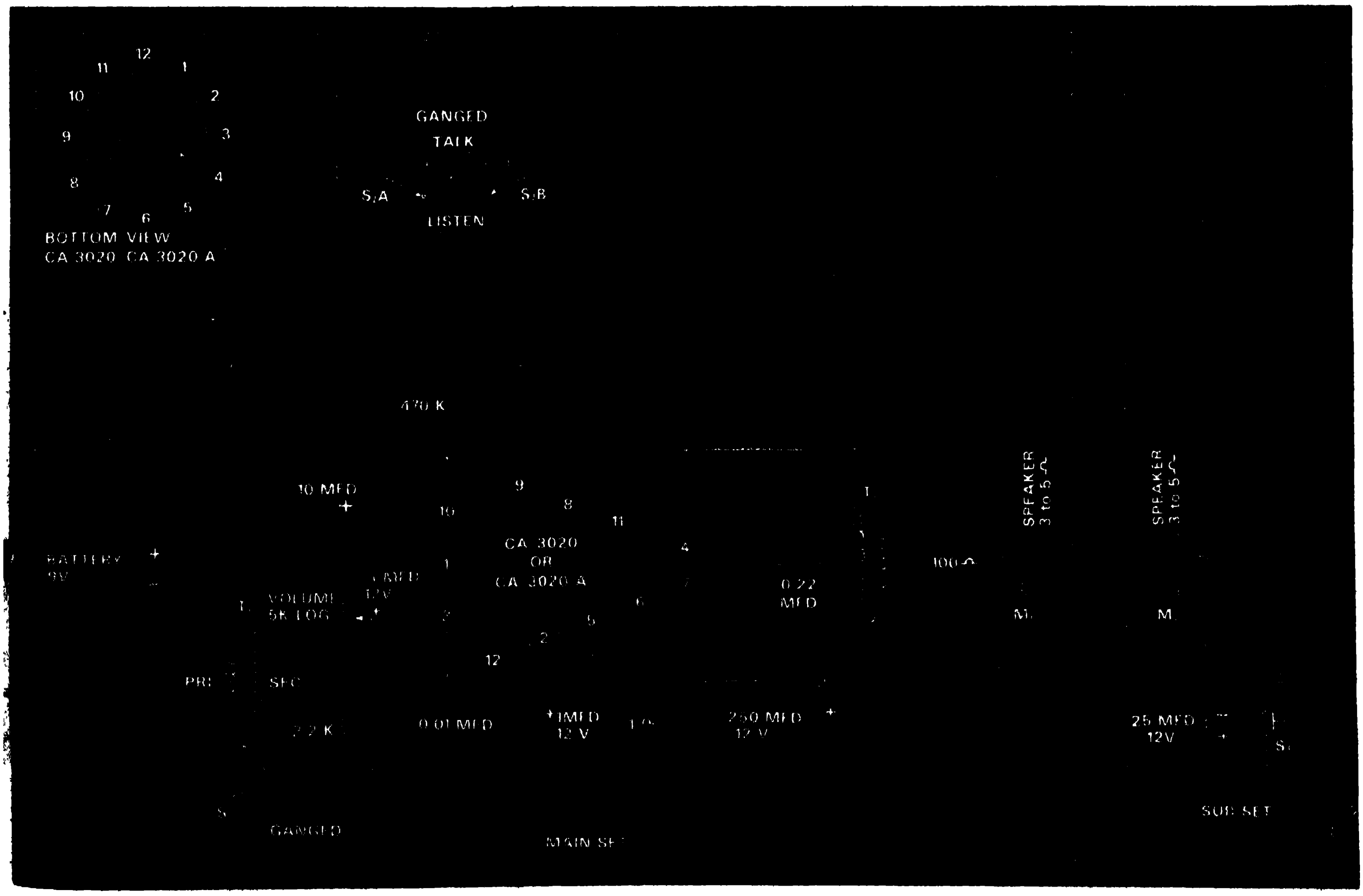
With the switch positions as shown in the diagram, the intercom set is "off". This is because the battery current cannot pass through the 25 mfd capacitor in the sub-set loudspeaker M2.

Call tone operation : If S2 alone is operated, then the battery gets connected to the IC amplifier circuit through the primary of the transformer T1 and loudspeaker M1. This initial current induces a corresponding emf across the secondary of transformer T1. As the voltage induced in the secondary supplies the input to the amplifier, and if the secondary is the right way round with respect to the primary, i e, in proper phase relation, then this input will make the amplifier draw more current through the battery. This will cause a regenerative action. When the increase in current of the amplifier, as the result of increase in input to the amplifier ceases, i e, when the amplifier saturates, the magnetic field around the primary collapses. This induces the voltage in the secondary again, but this time in the direction opposite to that previously induced. This retards the flow of current drawn by the amplifier till it reaches the bare minimum value. This current is much less than the 'normal' current drawn by the amplifier without any input. With the amplifier current at this minimum level, no voltage will be induced in the secondary of the transformer T1. There being no input, the amplifier will try to take its 'normal' current. This will, once again, induce the positive going input and the process will repeat. The whole action will occur at such a fast rate that each cycle will take a few milliseconds and what you will hear through the sub-set loudspeaker M2 will be audio oscillations as call tone.

Now, suppose S3 is closed, keeping S1 and S2 as shown in the diagram, then the battery current will pass through the primary of transformer T1 and loudspeaker M2 instead of loudspeaker M1. Similar oscillator action, as explained above, will take place and you will hear the call tone through the loudspeaker M1.

If the amplifier ceases to operate as an oscillator by operating either S2 or S3, then interchange the connections of either the primary or the secondary of the transformer T1, to give the feedback in the proper phase which will cause oscillations.

It is clear from the above explanation that when S2 alone is operated, the loudspeaker M2 gets connected at the output terminals of the amplifier and if S3 alone is operated, M1 gets connected at the output terminals. So



when S2, which is at the main set, is operated, it gives the call tone at the sub-set and when S3, which is at the sub-set, is operated, it gives the call tone at the main set.

Two-way Communication: When the call is attended to by the person at the other set, the switch S1 is to be switched on and S3 has to be switched off. This time the transformer T1 will act as a step-up component between the amplifier and the loudspeaker acting as the microphone. The listen-talk change-over can be operated by switch S2.

The output transformer T2 is readily available in the market. The transformer T1 is a special step-up transformer with primary to secondary turns ratio of about 1 : 30 or more. You can get this transformer made to order from any transformer manufacturer or you can wind it yourself with the details given below. If the size of the transformer T1 is not of much importance, then you can use the standard ready-made output transformer suitable for vacuum tube EL 84. While using this transformer, connect the normal low impedance secondary as primary, and vice versa.

Precautions: To avoid the interference of the mains supply, connect the laminations or brackets of both the transformers to ground, as shown in the diagram and, as far as possible, keep the wiring between the main and the sub-set units apart from the mains supply wiring. If required, you can use the standard 9V battery eliminator to replace the battery.

The main set and the sub-set, during testing, should be kept at least 3 metres apart to avoid the squealing sound caused by feedback through the air between the speakers.

Construction of transformer T1 :

Material required: 1. Enamelled copper wire; 43 SWG, 50 gm; 2. Core type: 17 CRGO grade 51, 100 gm; 3. Bakelite bobbin: Type 17 square ½ in × ½ in — 1 no.

Primary: 50 turns of 43 SWG enamelled copper wire.

Insulation: Interwinding (between primary and secondary) paper insulation.

Secondary: 1,500 to 2,500 turns of 43 SWG enamelled copper wire. Interlayer insulation not required.

You will need:

Integrated circuit: CA 3020 or CA 3020A, 1 no.

Capacitors: Electrolytic: 250 mfd 12 V, 1 no., 25 mfd 12 V, 1 no., 10 mfd 12 V, 1 no., 5 mfd 12 V, 1 no., 1 mfd 12 V, 1 no., polyester or ceramic: 0·22 mfd 1 no., 0·01 mfd 1 no.

Resistors (all ½ watt): 470K Ω, 1 no.; 2·2K, 1 no.; 100 Ohms, 1 no., 1 Ohm, 1 no.

Volume control: 5K Ω logarithmic carbon with switch, 1 no.

Transformer: For T1: (see text for material and constructional details) or

Output transformer for EL 84, i e, Pri.: 5 K Ohms; Sec.: 3-5 Ohms, 1 no.

For T2: Push-pull output transformer 500 mW pri: 100-180 Ohms, sec: 3-5 Ohms, 1 no.

Loudspeaker: 500 mW type 3-5 Ohms, 2 nos.

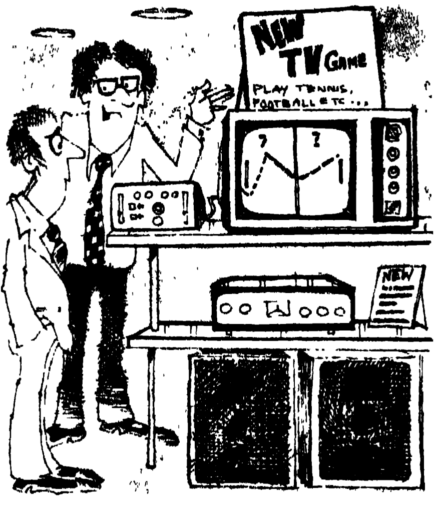
Switches: S1: Provided with volume control; S2: Two-pole, two-way (preferably self-resetting type) 1 no.; S3: normally open push button type.

Supply: 9 V battery 276-P type or 9 V battery eliminator, 1 no.

Misc: Screws, solder, wires, knobs, suitable enclosures, veroboard, etc.

The approximate cost of the components is Rs. 110.

ANIL V. BORKAR



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BRAIN TEASERS

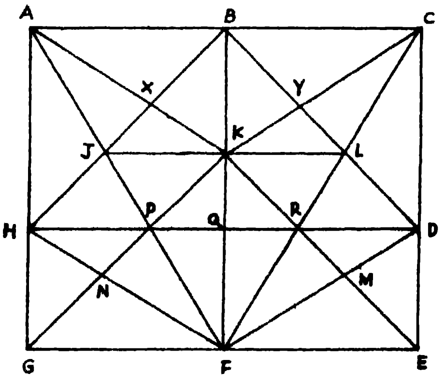
FAMILY AFFAIR : The principal of a college invited me to tea with the heads of the sections of his college. I learnt that they were a happy family (in more than a figurative sense) with five members; all but one held some important office in the college. Prof. Chatterjee is the principal's father-in-law and Prof. Doshi is his (principal's) brother-in-law. The vice-principal is going to marry the principal's cousin. Prof. Eshwaran's wife is the sister of the students' counsellor.

That day, apart from the principal, I met the hostel warden, Prof. Eshwaran and Prof. Doshi. The following week, I met three of them in a cinema theatre. One of them, Prof. Banerjee, I met for the first time. The others were Prof. Acharya and Prof. Doshi. What office, if any, does each of them hold ?

V. A SHENAI

MANY-IN-ONE: How many triangles are there in the figure below?

SHAIK MAHMOOD



(Solutions next month)

Answers to last month's Brain Teasers

How many students ?

The last two digits in the product indicate that the numbers of students have 3 and 7 as their last digits. Let X and Y be their first digits, so that 10X + 3 and 10Y + 7 are the required numbers.

Now $(10X + 3)\ (10Y + 7) = 2021$

ie, $100XY + 30Y + 70X + 21 = 2021$

ie, $10XY + 3Y + 7X = 200$

Let $X - Y = K$

substituting $X = K + Y$,

$10\ (K + Y)\ Y + 3Y + 7\ (K + Y) = 200$

Rearranging,

$10Y^2 + (10K + 10)\ Y + (7K - 200) = 0$

This is a quadratic equation in Y and its positive root is given by

$$Y = \frac{-(10K+10)+\sqrt{10^2(K+1)^2-40(7K-200)}}{20}$$

$$= \frac{-(K+1)+\sqrt{(K+1)^2-2.8K+80}}{2}$$

$$= \frac{-(K+1)+\sqrt{K^2+2K+1-2.8K+80}}{2}$$

In this case Y will be rational only if K = 0. In that case,

$$Y = \frac{-1+\sqrt{81}}{2} = 4.$$

So X is also 4

The required numbers are 43 and 47.

Oversight

Suppose M is the price of each mathematics book and C of each chemistry book, and Nm and Nc are the numbers of mathematics and chemistry books bought.

$NmM + NcC = 1150$

Then, $NmC + NcM - NmM - NcC = 100$

$(Nm - Nc)\ (C - M) = 100.$

Now, $C - M = Nm - Nc$. Therefore, each must be equal to 10.

ie, $Nm - Nc = 10$

But $Nm + Nc = 60$

Hence, $Nm = 35$ and $Nc = 25$.

$C - M = 10$

$C = M + 10$

Also, $35M + 25\ (M + 10) = 1150$

So $M = 15$ and $C = 25$

TELL US WHY...

. . . animals' eyes shine in the dark?

If you prefer to be a stickler, you could say, they don't! In complete darkness, animals' eyes don't shine; they don't give off a light on their own. Technically, the question ought to be rephrased like this: Why do animals' eyes reflect light directed into them? Walk into the woods at night and flash a torch and you can see several such shining eyes: little pricks and glitters of topaz to let us know that there is a spider hiding in this shrubbery, glints of green witchfire to betray the presence of a stealthy fox behind that fallen log, a quick blaze of glowing red which could mean your torch beam has discovered a rabbit. Why doesn't it happen with human eyes?

The reason is, animals are largely nocturnal; the dark hours are when they do most of their hunting and prowling. Behind the retinas of these night explorers' eyes, instead of a dark layer of pigment, they have what amount to mirrors. The faint light in which they have to do their seeing — moonlight, starlight — is reflected by these mirrors and thereby multiplied. Nocturnal animals' eyes shine for the same reason that roadside reflector buttons shine.

Can cats see in total darkness? No, but they can utilise a minimum amount of light much better than humans can. With such sensitive vision in very dim light, then, why aren't they blinded in brilliant sunshine? Because they have slit pupils. They can narrow the slits, at noontime, until less daylight enters than through a pinhole.

While we are on this matter of animals' vision, let's consider several other questions that crop up frequently.

Is it true that a rabbit can see what is going on behind its back? Empty-handed hunters have often sworn this must be the case; and as a matter of fact, it is. Rabbits' eyes have such a protruding convexity that they can contemplate virtually a full circle.

Why are bulls said to be particularly excited by the red colour? They aren't. Bulls are colour-blind. Repeated experiments by a number of investigators of animal life have made it certain that bulls inhabit a visual world of only black and white and intermediate grays.

How about other animals? Are they all colour-blind? We cannot say with absolute certainty, of course, but among all the animals that have been studied in this respect, colour blindness has been found general with only two exceptions, monkeys and apes.

. . . why are some birds' eggs plain-coloured while others are speckled?

We'd have to read nearly a bookful of evolutionary oology to explore this fully, but putting it in the briefest and simplest way, it goes like this. Originally, we can take it, birds' eggs were all just yellowy-white like the eggs of their reptile forebears. With birds' development of the nesting habit as a protective device, the colouring of their eggs also became protectively adapted.

Take birds that nest in holes and dark, protected crannies of one sort or another — birds like kingfishers and woodpeckers. They lay white eggs. After all, their eggs are invisible by virtue of the nest environment. But take the eggs of killdeer plovers which are laid on the ground. They are streaked and mottled in such semblance of pebbly soil that they are almost invisible even when we are staring straight at them.

But then, what about solid blue and solid green and variously blotched eggs that we find among the birds that nest neither on the ground nor in holes but on trees? These, as the evolutionists put it, are probably degenerations, meaning that, whereas the pigmenting of eggs presumably started in the first place as a protection when all birds' eggs were laid on the ground, the pigmenting is now in the process of dying away among those birds that have taken to nesting in places where the eggs don't need it. If we do some nest exploring, we can soon find out that the eggs of a great many birds vary a lot in their colouring and markings. Phoebes' eggs are sometimes quite heavily speckled, and sometimes have no speckles at all. Sparrows' eggshell colours vary immensely, all the way from nearly white to such dense spotting as to be almost solid brown.

SUDHIR D. GHATNEKAR

[Dr. Ghatnekar is on the staff of the Biology Department of Ramnarain Ruia College, Bombay.]

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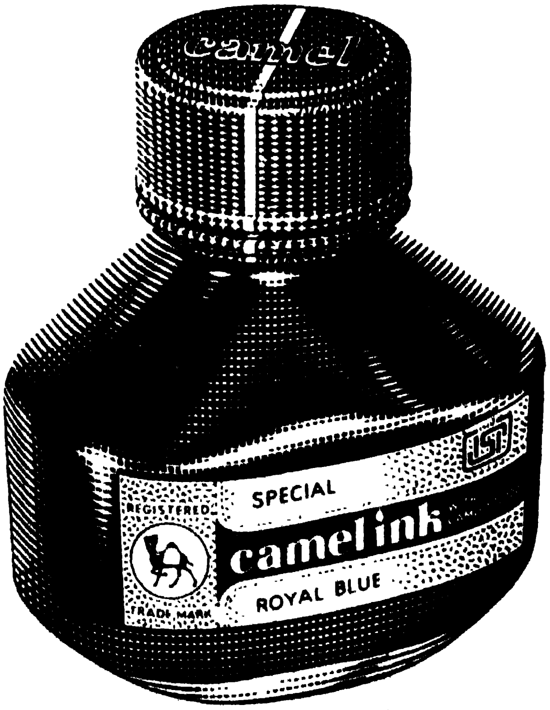

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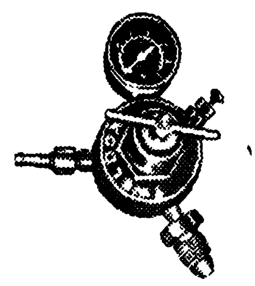

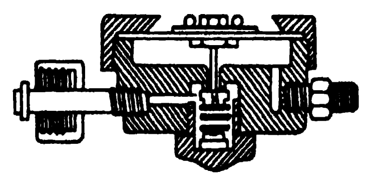

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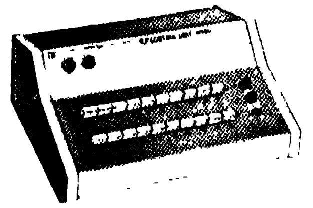

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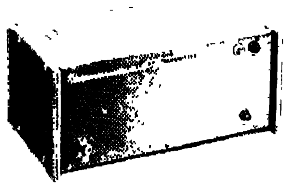

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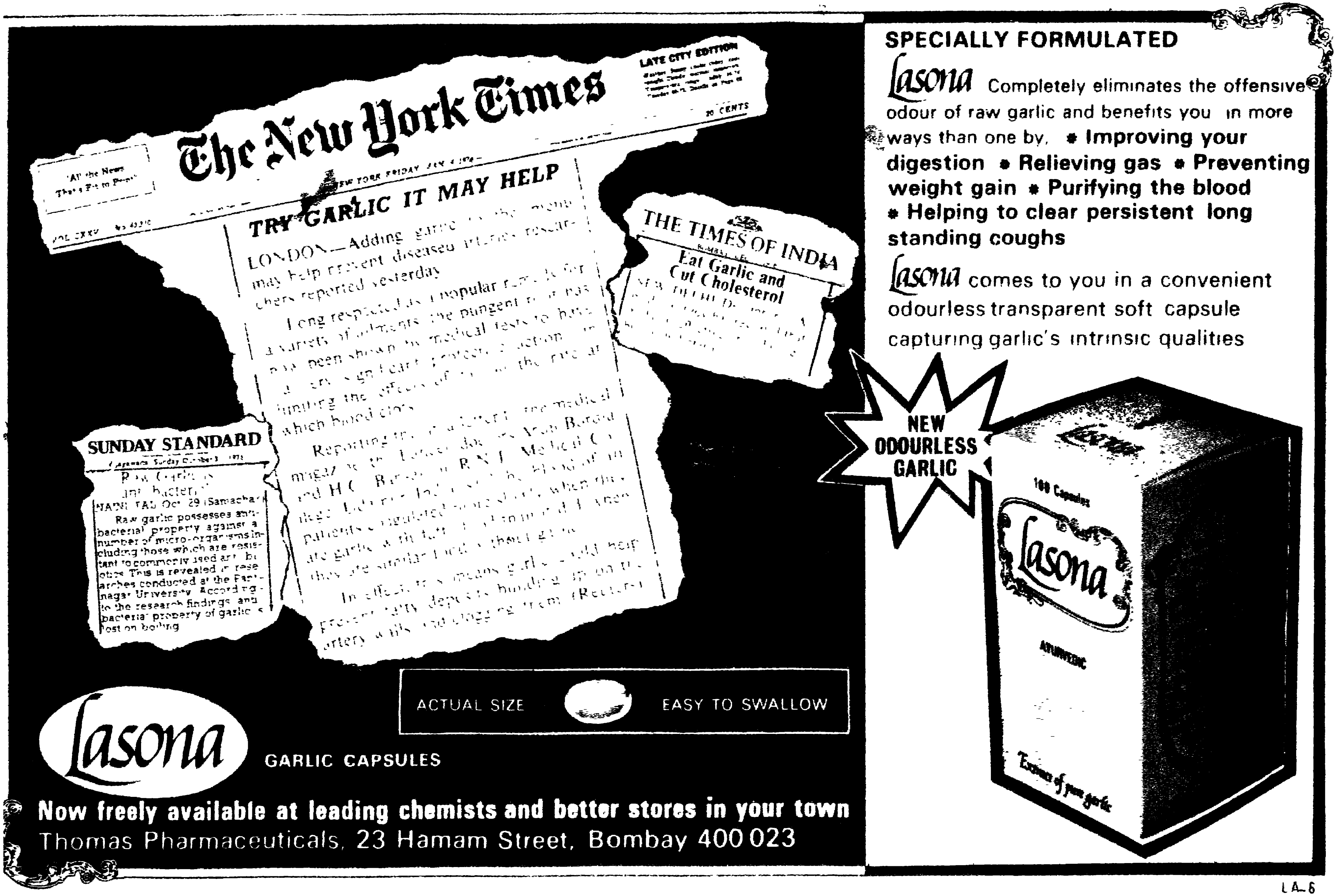

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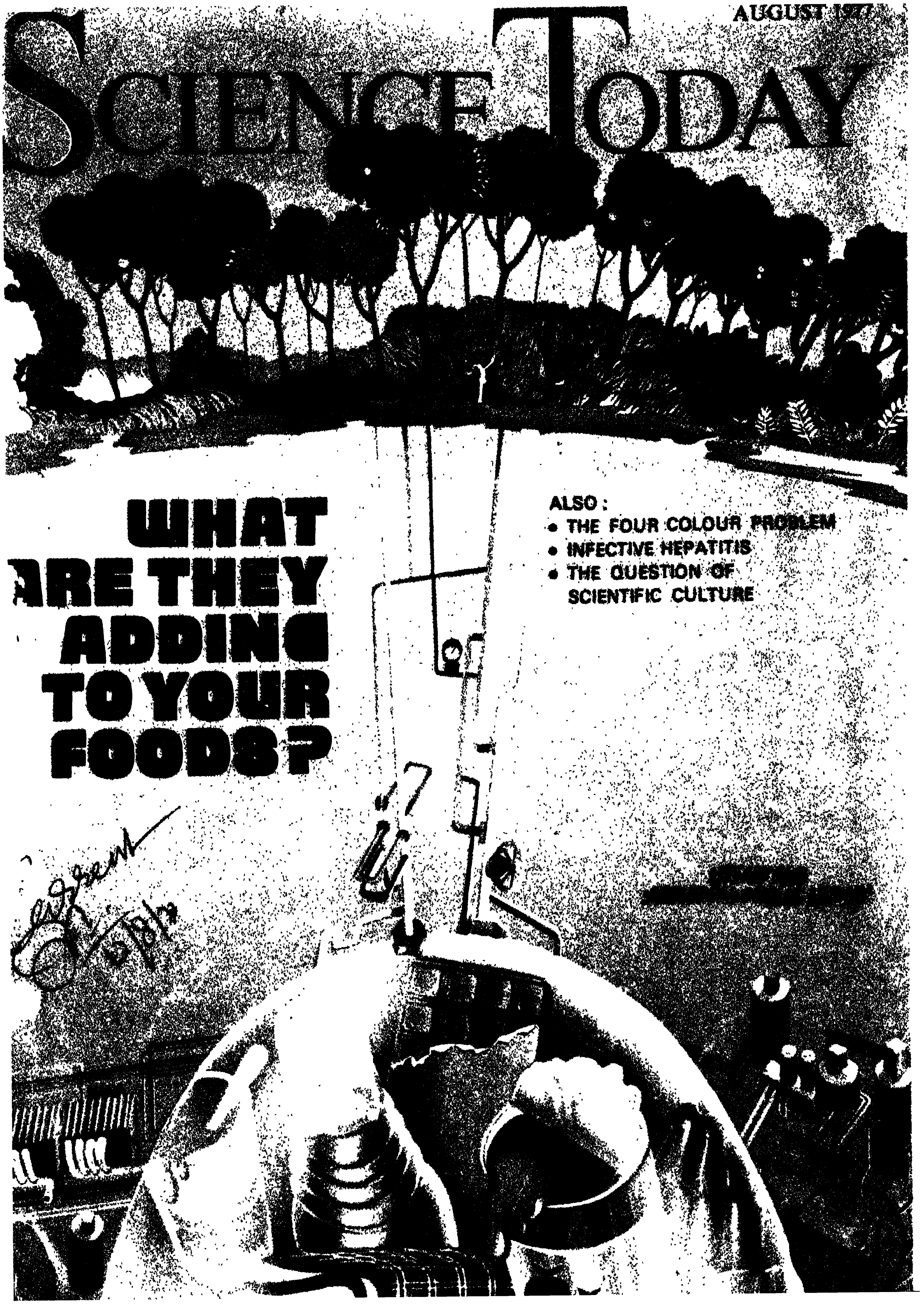

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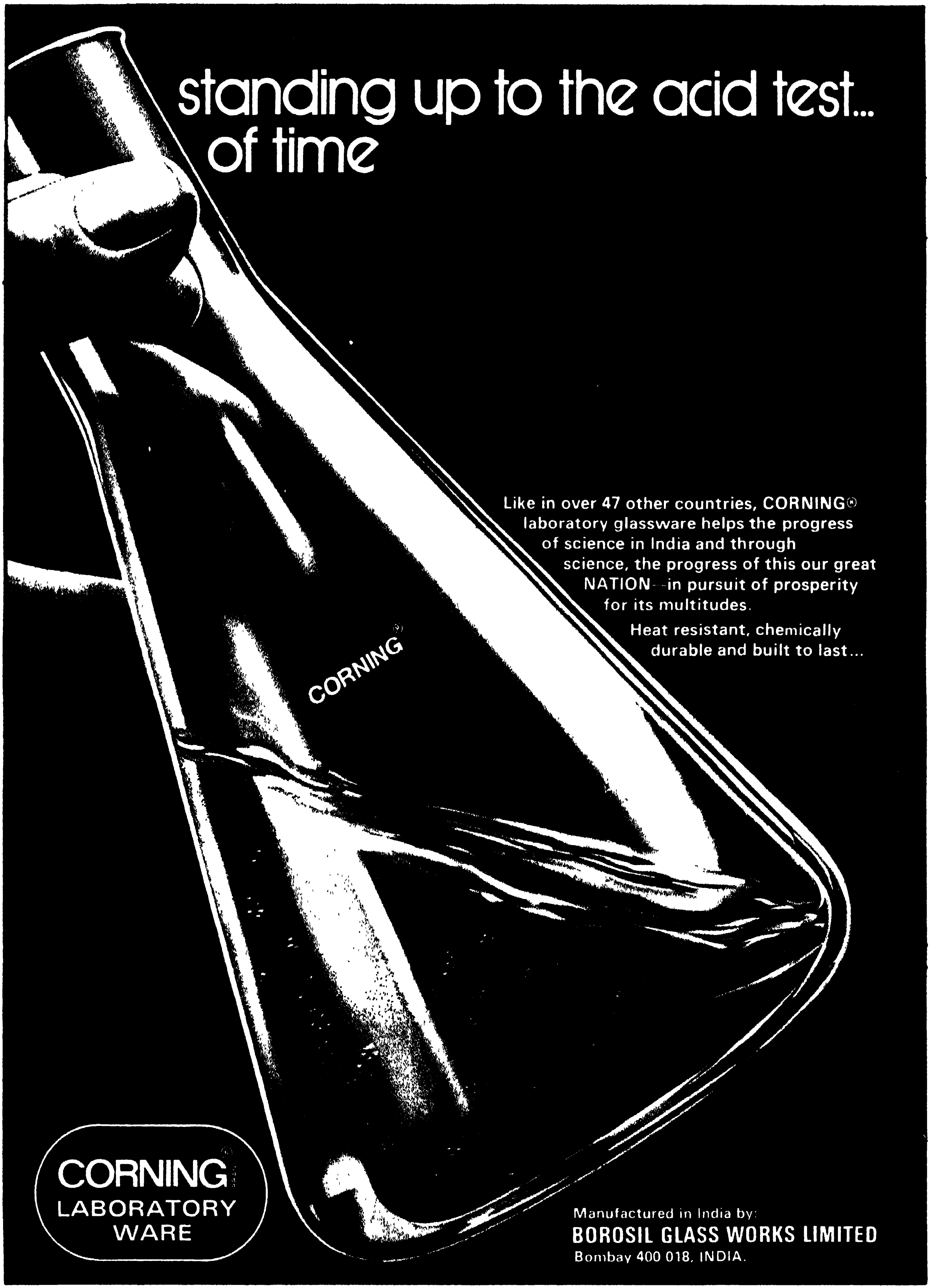

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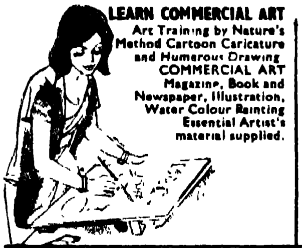

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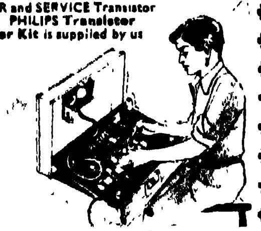

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SURENDR JHA

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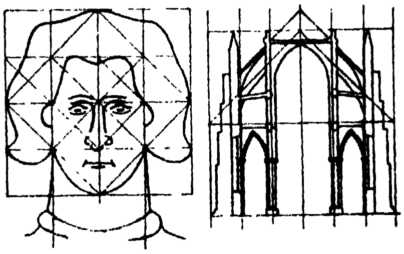
R. Narasimhan

How did the West overtake the Eastern nations from which it had borrowed the technologies in the first place? History has a few answers



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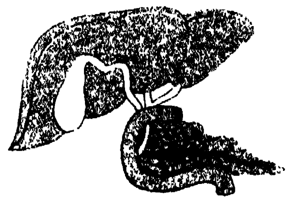
There are as yet neither specific vaccines nor drugs against the disease that turns the skin and eyes yellow. In fact, the causes are just being uncovered



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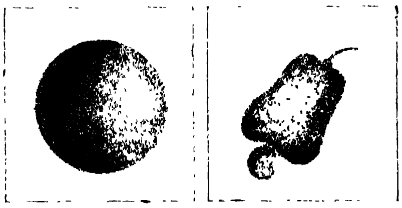

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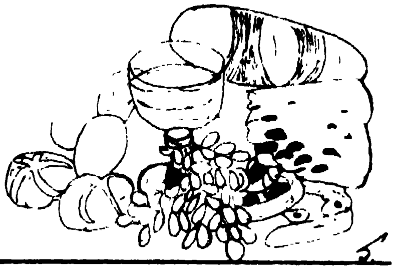
K. K. G. Menon

Colours, flavours, sweeteners, stabilisers, preservatives. Yet the problem of safety hounds every new, as well as old, food additive



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54 **WHAT IS A NEUTRON BOMB?**

LETTERS

Can fabric finishing processes harm the skin?

In " Cotton fabrics and finishing gimmicks " (April 1977), Dr. Shenai states that when cloth is subjected to treatments by chemicals such as sulphates of barium, calcium and ammonium, chlorides of magnesium and ammonium, formaldehyde and melamine formaldehyde, and DMDHEU, etc before finishing and marketing, the chemicals are left over on the cloth. Do these chemicals harm the skin of the person who wears it? If so, to what extent?

Dr. Shenai has also mentioned that optical whiteners used to give clothes a dazzling white effect absorb ultra-violet rays from sunlight and the absorption depends upon the concentration of optical whiteners. Do these ultra-violet rays adversely affect the health of the wearer of these garments?

D. V. V. SWAMY
20-77-2, Golla Veedhi
Chengalarao Peta
Visakhapatnam-530 001

Dr. Shenai writes : **The points are pertinent. Most of the chemicals used in textile finishing and applied to fabrics are washed off from the fabrics during their subsequent washing treatment; most of these chemicals are soluble in water. Compounds like ammonium chloride decompose into ammonia (which is given out) and hydrogen chloride, which is subsequently washed. Resin precondensates are also washed off from the fabrics. However, certain catalysts like zinc nitrate, magnesium chloride, etc may form insoluble zinc hydroxide and magnesium hydroxide, which may get deposited on the fabric, and are difficult to remove. It is likely that traces of these may remain in the fabric. About the toxicity of such chemicals, I have not come across any work carried out in this field.**

The second point about optical whiteners is more serious. While some work has been reported indicating that the optical brighteners themselves are not toxic, no study has been reported, to my knowledge, on the effect of the absorbed ultra-violet light on the skin of the wearer. However, cotton cloth treated with optical whiteners and exposed to sunlight has been conclusively shown to undergo more damage than cloth without the optical whitener. Therefore, at the moment, it is not possible to say definitely whether the optical whitener on clothes is harmful or not. Research needs to be done in this direction.

Relevant technology?

The contents of the advertisement " Relevant technology for the millions " by Hindustan Lever in SCIENCE TODAY (January 1977, p. 2) have come in for sharp criticism by the British journal *New Scientist* (10 March 1977, p. 591). *New Scientist* questions the HL claim that the beneficiaries in the *sal* seed business are the Adivasis. It says that most of the benefit goes not to the poorest, but the rich and powerful middlemen and a foreign controlled multinational, that is, Hindustan Lever.

It would be worthwhile to reproduce the following paragraph from *New Scientist* dealing with the so-called " benefits " to the Adivasis : " But what about the Adivasis? There are two keys to understanding how they have been affected by the *sal* boom. First, the *sal* season lasts a month or so. Second, contractors pay *sal* seed collectors only Rs. 3-4 per day. For each kilogram of oil, the contractor pays the Adivasi collectors only Re. 1 for the seeds, but receives Rs. 12 from HL. After processing the cocoa butter substitute, HL receives Rs. 20 per kg. The Adivasis see only 5 per cent of the value of their product ". The report goes on to say that by appropriate technology an equipment could be developed which could be used for processing the seeds by the Adivasis themselves by forming collectives. Since seeds can be stored, processing can extend over a large part of the year, thereby providing gainful employment to Adivasis, and increasing their income ten-fold.

V. VENKAPPA
Malaviya Regional Engineering College
Jaipur (Rajasthan)

Anti-amoebic combinations: are they therapeutically sound?

Currently, a large number of anti-amoebic drug combinations are flourishing in the market. Many of these contain at least three different groups of drugs : (i) an intestinal amoebicidal agent — iodochlorohydroxyquinoline or diiodohydroxyquinoline ; (ii) an extra-intestinal amoebicidal agent — chloroquine phosphate ; and (iii) an antibiotic — tetracycline or oxytetracycline. These do not act directly on the pathogenic amoebae but act by interfering with the enteric flora essential for the growth of the amoebae.

Practically, all these preparations are recommended for use as two tablets or capsules three times daily. An examination of the components of these combinations reveals that preparations Nos. 1 (Alliquine Fort tab), 2 (Amicline tab), 3 (Amebiotic cap), 4 (Iodocycline tab), 5 (Triquin cap), 6 (Amebide T.C. tab), 7 (Tequinopil tab) and 9 (Antecline tab) provide chloroquine phosphate as a maintenance daily dose (500 mg/day) which is less than the adequate quantity of 1 gm/day required for initiating the treatment, while preparation No. 8 (Esticline tab) has an adequate dose for starting the therapy but this is too high a dose for the maintenance therapy. The problem of providing the correct dose of chloroquine has been posed only because of the currently much employed " fixed dose " pattern of therapy which can cause both under- and overdosage problems, of which this is a glaring example.

In a large number of these preparations — Nos. 2, 4, 7 and 9 — the antibiotic is present in a sub-therapeutic dose ; the daily administration may be much less than the normal 1 gm required. It is, therefore, not only ineffective but positively harmful as it is likely to cause resistance in the micro-organisms. Moreover, in preparations Nos. 1, 2, 4, 5, 6, 7 and 8, the antibiotic included is tetracycline instead of oxytetracycline, despite the fact that the latter is superior. Preparation No. 7 has also a low dose of quiniodochlor (iodochlorohydroxyquinoline).

In our opinion, none of these combinations is suitable for both initial as well as maintenance therapy in amoebiasis. We are, however, seriously concerned with the composition of preparations Nos. 2, 4, 7 and 9, that is, Amicline tab, Iodocycline tab, Tequinopil and Antecline, which, for reasons given above, result in wasteful expenditure by sub-therapeutic doses of tetracyclines. We feel that this is a glaringly preposterous state of anti-amoebic combinations in our country and hope that the Drug Control Department will look into these serious inconsistencies.

P. C. DANDIYA
Professor and Head
Department of Pharmacology
S. M. S. Medical College
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J. S. BAPNA
S. K. PATNI
University College of Medical Sciences
Ring Road, New Delhi-110 016

Remote pressure indicator

The remote pressure indicator (April 1977, p. 47) claimed to have been developed by Mr. H. C. Sharma is not new to those who are acquainted with Russian process control instruments. An identical principle has been extensively used long ago by the Russians in their Bϕ series instruments. Further, there is no question of commercialisation of Mr. Sharma's instrument since, based on the same principle, Instrumentation Ltd., Kota, has already produced, in collaboration with Russia, a series known as FM (ferrodynamic monitoring). Both Bϕ and FM series instruments have already been used on a large scale in the Bokaro and Bhilai steel plants.

N. GOPINATH
S. RAMMOHAN
MECON, Ranchi-834 002

Guns with magnetic ring

The new gun which requires the owner to wear a magnetic ring to fire it (May 1977, p. 9) may not always be fired only by the owner as far as criminals are concerned; the magnetic ring may become a common item in the underworld. However, the magnetic ring may prevent several fatalities from guns going off accidentally.

BHUMESH MATHUR
Junior Executive Trainee
Fertiliser Corporation of India Ltd,
Bombay-400 074

LIFE MOLECULES IN MARTIAN DUST CLOUDS

Hoping against hope seems to be the distinguishing trait of the would-be founders of Martian biology. Viking's biology experiments were a let-down, but, after all, the probes sampled only two points on the planet's surface. A much broader sample of Martian surface material could be present in dust clouds such as those witnessed in the 1971 storm by the Mariner 9 probe, say H. Abadi and N. C. Wickramasinghe of the University College, Cardiff (UK); in fact, the spectrum of these dust clouds shows a feature which Fred Hoyle and Wickramasinghe had earlier considered as the signature of highly complex organic molecules in interstellar dust (see SCIENCE TODAY, May 1977, p. 11). The "absorption band" in the spectrum, which has a wavelength close to 2,200 Angstroms (1 Angstrom = 10^{-10} metre) has been found in a wide class of organic molecules. More accurate and extensive spectroscopic studies of Martian dust clouds may throw light on the question of complex organic molecules and primitive life-forms on Mars, say the scientists in a report in *Nature* (23 June, 1977).

PARACHUTE FOR MINES

A unique parachute developed by the US Interior Department's Bureau of Mines unfurls to block the flow of dangerous gases in mine explosions or to direct the flow of fresh air wherever it might be needed. Anchored to the ceilings of walls and passage-ways, the prototype chute has a sturdy hemispherical centre to contain air flows and a squared-off skirt that flares out to fit into irregularities in the rocky walls or ceilings. Tests are being conducted.

SHOULDN'T WE BE AT THE OTHER END?

ECSTASY THROUGH ENEMA

The hallucinogenic route to Paradise was known to the Mayas, the creators of one of the most flamboyant and intellectual civilisations of the New World, but they used an unusual short-cut — the enema — to reach there sooner.

The first evidence of this ritual was found in a Maya vase dating from the classic Maya phase (third century to seventh century AD). The vase depicts seven male-female pairs in horizontal rows: one of them is shown having enema administered to him by his consort; another is doing it himself. In between the couples are vases full of a foaming, fermented liquid, probably balche, a common alcoholic drink at the time of the Spanish Conquest. Writing in *Natural History*, March 1977, Peter T. Furst and Michael D Coe conclude that the people in the vase are taking intoxicating enemas, a practice previously unrecorded for this culture.

Obviously, the Mayan Indians had discovered that the rectal administration of intoxicants could alter one's state of consciousness more rapidly and with fewer side-effects than taking them through the mouth. The principal function of the large intestine is to reabsorb liquids into the system and to store wastes until they can be evacuated. A liquid injected into the rectum immediately enters the bloodstream, which carries it to the brain. In the rapidity of its effect, a rectally injected intoxicant or hallucinogen closely resembles an intravenous injection.

The elucidation of the scene depicted on the vase has also made clear previously enigmatic scenes in Maya vases from central Veracruz. Hitherto, these were considered as representing human sacrifice, but the expression on the faces of the reclining males is of ecstatic trance, not death; the posture — legs raised or propped over a support, with the feet up in the air — also suggests the intoxicating enema.

Thus, while in the Old World the enema has been used — even in the ancient civilisations — primarily for clearing the bowels, the native Amerindians used them to introduce medicine and intoxicants into the body.

THE TWILIGHT OF THE ORANG-UTAN

The gentle 'man of the woods' — the orang-utan — seems to be on the way out. All over Malaysia and Indonesia, reckless logging is wreaking havoc with his forest home. Perhaps the lessons learnt from rehabilitating the orang-utan in rehabilitation centres could open a few eyes amongst those in India who are trying to find new homes for declining species like the Gir lions.

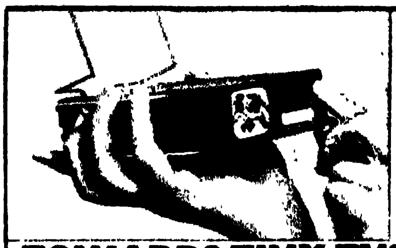
About a thousand orang-utans are made homeless every year by forest clearance. These, as well as animals confiscated from smugglers who meet the demands of pet-fanciers, are sent to rehabilitation centres at Sepilok and Bohorok, but the record of these stations has not been impressive. Many animals have died of sickness or predation. The objective ultimately is to return them to the wild population, but this has been rarely successful. Homeless orang-utans become bad tempered, and, since orang-utan biochemistry is similar to man's, they acquire human diseases from contact with humans; hence, releasing physically and psychologically sick animals into a healthy wild population has its own dangers. Worse still, some of the stations have been promoted as tourist centres, which probably makes it difficult for young orang-utans to revert to the wild life they hardly know.

ANOTHER CONFESSION OF FRAUD...

When a scientist's work cannot be repeated by other scientists, there is the suspicion of error, or even tall claims! The case of Dr. Summerlin and his painted mice in the USA is of recent memory.

The latest poseur is Dr. Robert Gullis who worked at Birmingham University (UK) and later at the Max Planck Institute for Biochemistry in Munich (Germany) on the effect of neurotransmitters, or chemical messengers (like noradrenaline), on cell membranes derived from guinea-pig brains. Eventually, Dr. Gullis got his PhD on the basis of this work. Now in a statement published in *Nature* (24 February 1977), he has confessed that the extensive data relating to his work and published in *Nature*, *The Biochemical Journal*, etc. were not experimentally determined.

What Dr. Gullis had apparently done in his PhD work was to show that a certain



TOWARDS TINY TVS

Bigness is not everything, not even in TV screens. In many of the portable TV sets being put out in Western countries, the small screens make the image look sharper and crisper, just as a wallet-sized photo often hides the blurs and imperfections of an enlargement. The picture quality in these small sets is excellent. One of the hottest new take-alongs is a set having a 5 cm diagonal screen and weighing 570 grams. Costing $300 (about Rs. 2,500), the set manufactured by a British concern, is smaller than the average paper-back book.

reaction in the cell membrane was affected by 'messenger' substances on both sides of the cell wall, thus affecting the membrane's properties. The crucial stage was the measurement, by means of a 'scintillation counter', of the uptake of a fatty acid labelled with a radioactive isotope, and it is here that the fraud was alleged to have taken place at Munich. It was detected when other workers, including those at the Munich Institute, were unable to reproduce his results. Dr. Gullis admitted that his data were not based on bonafide experiments, and wrote to *Nature* confessing that eight papers of his were based on "hypothesis"

Apart from the time that Gullis himself has wasted, it is estimated that at Birmingham alone, researchers have wasted four man-years vainly trying out Gullis's methods.

Gullis's motive? The same as Dr. Summerlin's — the craze to produce results "They were just after results," he says of the University authorities. What made it easier to fudge the results was that they were *expected*!

One unsolved problem for *The Biochemical Journal* is what to do with papers awaiting publication which cite Gullis's work.

VACCINES MIGHT SPREAD DISEASE GERMS

Eternal vigilance is the price of freedom from disease. The fact that no cases of a human disease have been reported does not mean that it has died out. It may be lurking in an animal population or may be in the process of mutating into a new strain (like the influenza viruses). Another possibility is that where an attenuated live virus is used for inoculation as in the Sabin polio vaccine, strains similar to the vaccine strain may gain a foothold in the population. More so, because the remarkable success of the polio vaccine has encouraged the use of attenuated live viruses against other common virus infections

In England and Wales, though polio cases have become fewer since the live (Sabin) vaccine was introduced in 1962, many strains are still being isolated from apparently healthy persons who have neither been vaccinated nor have had contact with a recently vaccinated person. Dr. Yvonne E. Cossart, a bacteriologist now with the University of Sydney, Australia, compared such strains with those from suspected poliomyelitis victims in the UK. She found that the virus had changed its character over a decade or so. Before the introduction of the live vaccine, most strains could multiply at raised temperatures. Now, many strains from polio victims or from apparently healthy persons cannot reproduce above 37°C, and in this they resemble the vaccine strain. The disease has also changed: whereas in 1957, 66 per cent of polio victims had the classic symptoms, now less than one-half are paralysed.

However, since the wild strains and the vaccine-like strains differ only slightly, it is important that immunity to the former is maintained by vaccination, Dr. Cossart cautions in a paper in the *British Medical Journal* (25 June, 1977).

AN ABM BEAM

American military circles seem to be agog with rumours, set off by an *Aviation Week* article last May, that the Soviets have developed a particle beam weapon as their anti-ballistic missile defence. The supposed evidence for the report consists of reconnaissance satellite pictures of certain installations at Semipalatinsk and at Azgir (near the Caspian Sea): at the latter site there is a large main building with an underground granite cavern nearby in which there are two thick hollow spheres; pipes lead from the chamber. According to the journal, the granite chamber is a fission explosion generator, using a train of nuclear explosions to drive metal through a magnetic field. From the generator, power is carried through cables to giant capacitors in the surface building. Power from the capacitors is fed into a 'collective accelerator' and an electron injector gun to produce a beam of protons.

One advantage with a particle beam weapon would be that, travelling at the speed of light, it could reach its target much sooner than a conventional missile interceptor, but aiming it could be a problem, because deflections in the Earth's magnetic field could tug the beam about.

Sceptics say that the 10 megajoule energy level that the device would require to destroy a target could as well be obtained from a conventional high explosive. Writing in *Science* (27 May 1977)

DO AGEING STARS STOKE THEIR FIRES?

Looking at the extreme ultraviolet (EUV) part of a star's spectrum has been an eye-opener for astronomers, and may well revise our ideas about what happens to a star in its old age. (The extreme ultraviolet lies in between the far UV and the soft X-ray region of the spectrum; most astronomers had believed that it was useless to expect to see stars in the EUV because the junk in interstellar space—mostly hydrogen—would absorb all the radiation.)

But Stuart Bowyer and his associates at the University of California (USA) thought otherwise. They felt that interstellar matter is not of uniform density, in between the denser patches, the density is only one-tenth the average density.

Bowyer's group flew a EUV telescope on the Apollo-Soyuz joint mission (1974). (The telescope has no imaging capability but determines if a given source is radiating EUV.) One surprise of the experiment was the finding that the hot white dwarf HZ43 in Coma Berenice (a white dwarf is a star that having exhausted part of its nuclear fuel occupies a much smaller volume and has a high surface temperature) has a high temperature of about 110,000°K—which is 17 times the surface temperature of the Sun and is high even for a white dwarf. The dark companion (Sirius B) of the Dog-star, Sirius, turned out to be 10,000 times as bright in the EUV as it is by visible light and its temperature is read as 30,000° to 35,000°K. (Sirius B by optical light is a small faint dwarf dominated by its giant companion.)

Sirius A outshines Sirius B (at top)

According to Bowyer, such results, especially for HZ43, might necessitate changes "in the theory of the end point of the evolution of a star".

Nicholas Wade opines that, at the most, the Soviets may possibly be experimenting with a particle beam weapon.

SUICIDES AND MOTOR ACCIDENTS

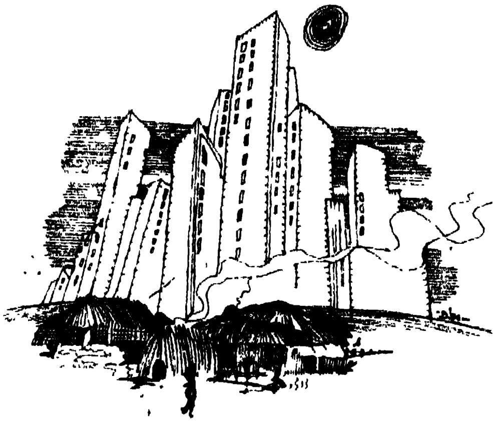
In the USA, publicity given to suicide stories in newspapers was found to have a direct relation to motor vehicle fatalities. A paper published in *Science* (24 June 1977) by sociologist David P. Phillips of the University of California at San Diego, USA, says that the rise apparently occurs because some persons tend to imitate the publicised act. Earlier, in 1974, Phillips had shown that suicide levels rose after publicised suicide stories.

For his present work, Phillips examined the front-page suicide stories that had appeared in the Los Angeles *Times* and the San Francisco *Chronicle* and noted the corresponding weekly road fatalities. The correlation was quite extraordinary. For instance, road fatalities in California increased by an average 18·33 per cent during the week following the suicide of Japanese author Y. Mishima in 1970.

TOMORROW'S WORLD—A SLUM?

Dr. Samuel Chamecki, consulting engineer and head of UNESCO's research section in engineering sciences, says that already slums and slum-like settlements account for 33 to 50 per cent of the population of cities in developing countries. " One-third of the world's population is either currently homeless or housed in substandard lodgings ", he says.

And it is quite possible that architects and urban planners will be unable to do anything about it. Madhu Sarin, an Indian architect now at the University College, London, cites the case of Chandigarh, the well-planned (by La Corbusier) capital of Punjab. Chandigarh has a population of 250,000, 15 per cent of whom live in squattered settlements. " High rents and overcrowding have become the norms in low-income residential areas. While the rich (with ample economic choice) command space, the poor are trapped in it ", she says.



The sweepers, gardeners, rickshaw-pullers and hawkers that Chandigarh needs are provided by these ever-expanding slums. Sarin wonders how much progress these slums can make as long as the inhabitants remain at the bottom of an economic power structure.

The problem is not Chandigarh's alone. Will the cities of the future be large aggregates of ugly slums?

GENE-"SWITCH" SYNTHESISED

The on-off switch of a bacterial gene has been chemically synthesised, slipped into bacteria and observed to subvert normal gene control.

Researchers at Cornell University, USA, constructed a DNA segment that controls the group of genes involved in *Escherichia coli's* use of the sugar, lactose. The synthetic segments were linked into DNA plasmids and thus, carried into bacterial cells

Several laboratories are now attempting to attach such control segments to maintain genes to coax bacteria into making desired proteins such as insulin.

A SLOW VIRUS COULD CAUSE SENILITY

The belief that a virus could be behind human senility has come from an understanding of scrapie, a neurological disorder of sheep, kuru, a disease reported first among New Guinea cannibals, and Creutzfeldt-Jacob disease (see SCIENCE TODAY, December 1976, p. 51). These are all similar in that months or even years may pass before disease symptoms show up.

Now John Hotchkin and Ruth Buckby of the New York Department of Health, Albany (USA), have neatly demonstrated that in scrapie the infection is acquired at birth and has a long incubation period. The causal agent is unusual, not only in being extremely small but also in possibly lacking the nucleic acid common to all known life-forms.

The scrapie virus being transmissible to mice, the scientists inoculated newborn mice with it. The animals showed no signs of the disease for one year, but by 18 months began dying faster than a group of uninoculated animals (the 'controls'). The scientists suggest that the virus remains latent for about one year, then becomes active, multiplying in the thymocyte cells of the immune system and finally producing the disease symptoms.

Writing in *Science* (6 May 1977), the scientists say that their work has an important bearing on diseases similar to Creutzfeldt-Jacob disease and kuru disease, if infection occurs at birth, and there is a long incubation period, it would naturally make them difficult to distinguish from genetic diseases.

UNDERWEIGHT WOMEN AND THE PILL

Underweight women who have unpleasant initial experiences while taking to oral contraceptives would do well to remember that body weight is one of the factors which determine the action of a drug.

It has been noticed that women vary in their reactions to oral contraceptives, which are based on hormones; yet it would be complicated to take into account their internal hormonal make-up before prescribing the pill. One factor which can be studied easily is body weight, and last year it was reported that underweight women are more likely to miss their periods when they go off the pill.

Following this cue, Dr. Prem P. Talwar of the International Fertility Research Programme, North Carolina (USA), and Dr. Gary S. Berger of the University of North Carolina gave oral contraceptives, in three cycles, to 480 healthy women of reproductive age. Their physical traits like height, weight and blood pressure were recorded when the trial began. Every two weeks, a nurse phoned up the women to enquire about possible side-effects.

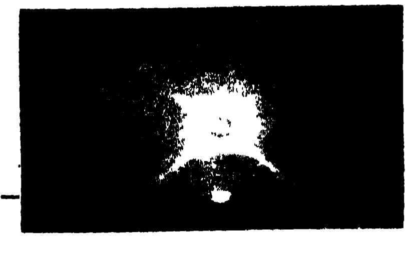
It was found that overweight women had the fewest side-effects like cramps, vomiting and depressions, as compared to underweight women. In the case of vomiting, the difference was most marked. Only in the case of headache did the overweight women suffer more. However, the authors note in their paper in the *British Medical Journal* (26 June 1977) that the differences tended to disappear in the third cycle and hence all women who experience side-effects with oral contraceptives should remember that these are likely to decrease by the third cycle of use.

THOSE "SHOCKING" DOG COLLARS

Some American dogs now wear a sound-activated collar which gives the animals an electric shock whenever they bark aloud. The collar which sells under such brand names as Wuf-E-Nuf and No-Bark Collar (at $40 each) has now come under fire after it was found that the collars sometimes produced a voltage 10 times that stated on their labels. Such high voltages, can burn a dog's neck. Worse still, any noise in the vicinity — car hooters, clapping hands, or another barking dog — can trigger off the collar unnecessarily.

SUPER-STAR

This remarkable photograph of the red giant star Betelgeuse indicates that it may be actually 400 times larger than our entire solar system. The picture was taken with new infrared enhancement equipment connected to the huge telescope at the University of Texas McConald Observatory (USA). The bright centre image is the star; the dot at the bottom is a ghost image. Betelgeuse, one of the best known stars in the winter sky, is in the constellation Orion.



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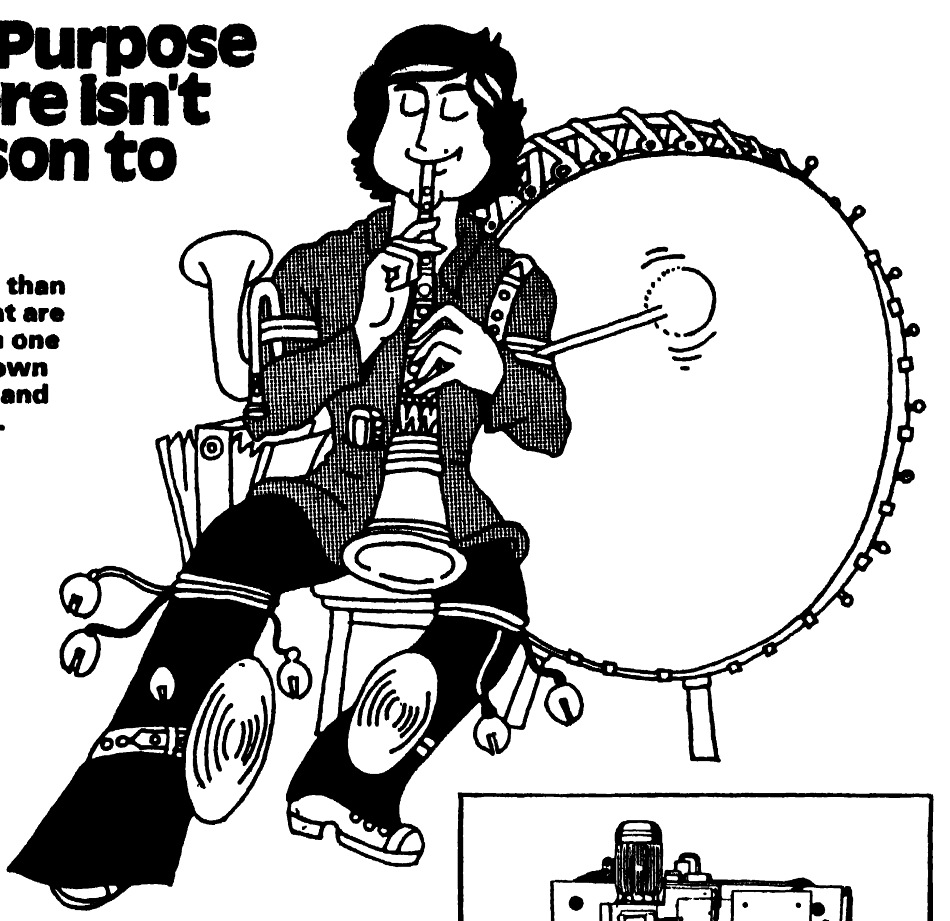

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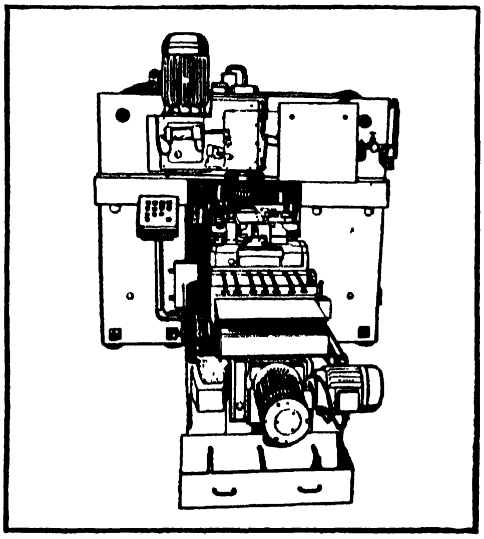

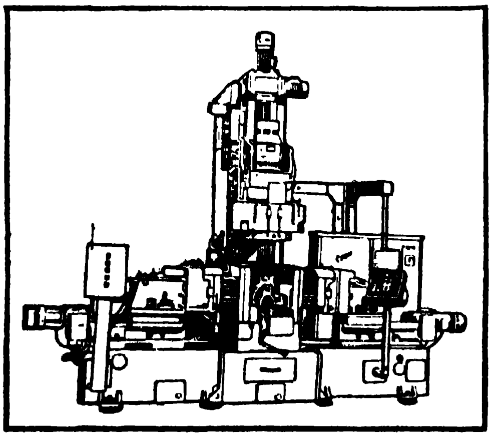

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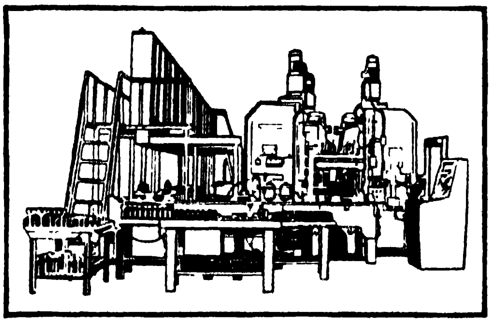

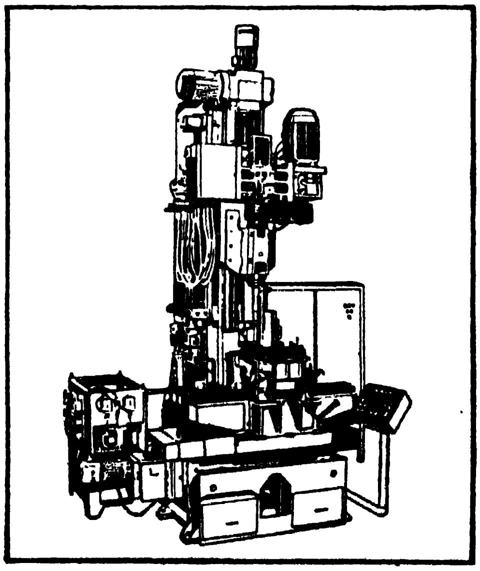

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BETWEEN US...

Does cattle-breeding help the rural poor?

Which way are our rural development programmes heading? "It has been our common experience," write two active workers from Kishore Bharati, a well-known voluntary rural development agency in Madhya Pradesh, "that when a technology demands a high level of capital investment and a wide contact with bureaucracy, industry and urban centres as preconditions for its adoption in rural areas, the benefits are usually siphoned off amongst the already economically and socially powerful rural elite." They express serious concern over the indiscriminate transfer of technologies to rural areas.

Their observations, based on their own experience as well as that of a few others, assume added significance in the context of the Janata Party's clearly stated commitment to an overall development of the agricultural sector, specially to the upliftment of the rural poor. The Janata Party programme has stressed the importance of animal husbandry, aqua-culture, agro- and rural-based industries, etc as tools for rural development. Particularly, "dairying has a great future based on the wealth of Indian cattle which can be upgraded", says the Party's election manifesto. But, how far have these measures really helped the rural poor?

Some of the issues raised by the two workers, Anil Sadgopal and Rex D'Rozario, need to be widely discussed. Dr. Sadgopal, one of the initiators of the over six years old Kishore Bharati, was until 1970 a researcher with the Molecular Biology Group at the Tata Institute of Fundamental Research, Bombay. Mr. Rozario, a former colleague on the editorial staff of Science Today, *joined the project three years ago. Below, we reproduce extracts from their letter*

It is often argued in defence of transfers of such technologies to rural areas that a 'percolation effect' occurs which benefits the weaker sections; the fresh inflow of investment helps in building up an agro-based industrial infrastructure, and this, in turn, increases the employment potential of the landless labour, the marginal farmer and the village artisan groups. However, the rate of increase in incomes of the rich and the poor as a result of introduction of such techniques is so disparate that the gap between the two is further widened. And the poor become increasingly dependent on the rich.

Our attempts at taking technology directly to underprivileged groups have encountered tremendous obstacles. The rural elite, intent on retaining their stranglehold on a semifeudal economy, fight tooth and nail against any drastic changes in the economic and social hierarchy. The bureaucracy and village-level extension services remain indifferent. Lack of finance inhibits investment and limits access to more remunerative markets. Industry often remains sceptical about the ability of such groups to successfully adopt a technology which demands proper management.

Let us examine this process, though briefly and rather superficially, with reference to the technology of cattle-breeding. We have surveyed and analysed various cattle-breeding programmes sponsored by the Government and voluntary agencies, including our own. The collective experience of using cattle-breeding as a tool in rural development has shown that the cattle-breeding technology is elitist. For example, take capital investment. Present trends in institutional financing put the cross-bred cow beyond the reach of the small and marginal farmer, the landless agricultural labourer, the village artisan, the petty shop-keeper and the Adivasis dependent on forest produce for a living. And these categories constitute over 70 per cent of the rural population.

The sophisticated nature of the technology is further illustrated by the technological tie-ups it demands. First, artificial insemination with frozen semen requires foreign collaboration for the supply of progeny-tested semen and insemination aids, liquid nitrogen manufacturing plants, and liquid nitrogen containers for storing the semen. Second, a cross-bred cow demands intensive veterinary care, and this brings the pharmaceutical industry into the picture for the supply of expensive veterinary formulations and vaccines. And then, when the market for milk is saturated, there is pressure to convert milk into products like butter, milk powder, cheese, etc. The capital-intensive conversion technology comes from the large industries, followed, in its wake, by high-salaried dairy technologists and managers. Rural areas thus come to increasingly depend on sophisticated technology, industrial expertise and high finance. Soon this siphons off a significant portion of profits, for the maintenance of high-salaried dairy technologists and managers. Large marketing networks and intensive advertising campaigns to sustain and widen the market cut further into the profits. The owner earns progressively less.

Given the more remunerative prices and greater demand for milk and milk products in urban areas, the phenomenon of rural areas depending upon, and producing for, urban markets soon becomes an unavoidable reality. And in trying to reach these markets, fresh relationships have to be created with the bureaucracy — transport, licensing and taxation officials, and veterinarians.

Policy-makers ignore another important aspect of cattle-breeding. The large green fodder requirement of a cross-bred cow makes it necessary to convert much-valued land under cereal production to the cultivation of fodder and ingredients of feed concentrates. Expensive irrigation facilities and scarce fertilisers, too, are diverted. In the process, there is a loss by a factor of about five in the total energy output per acre of land in terms of available food. That milk contains much-needed proteins for bridging the protein gap in India is not valid. What we lack is sufficient calories, not protein. Milk has no special advantages over a combination of cereals and pulses with regard to calories and essential amino acids.

The large farmer and trader will, of course, strongly lobby for the adoption of this technology. It is more remunerative and, therefore, in their interest. With the greater buying power they acquire, they soon increase the demand for unnecessary consumer goods and perpetuate a pattern of industrial growth that is irrelevant and damaging to the weaker sections.

The national policy of cattle breeding has thus favoured the elite. How can this policy be modified to help the poor?

Are there any alternative cattle-breeding technologies which can lead to economic and social equality in rural areas? Can cross-breeding be made less dependent on high finance and industrial and urban collaboration? How can one alter the existing cattle-breeding techniques so that cattle development will be relatively free of the critical influence of multinationals and international aid agencies? Can one design and carry out experiments to test various possibilities like: (*i*) converting marginal land into rain-fed pastures; (*ii*) using liquid semen stored in coconut water or other cheap media in place of more expensive frozen semen; (*iii*) evolving low-cost refrigeration techniques for semen and milk storage; (*iv*) improving and rationalising local veterinary medicines; and (*v*) re-organising the infrastructure for the supply of concentrates, vaccines and modern drugs so that they reach the poor without the interference of intermediaries like traders and the bureaucracy?

Why, in fact, is there a disproportionate interest in cross-bred cows? Why not buffaloes or goats? No doubt, the cow is a more efficient machine and can be improved genetically through cross-breeding, both in terms of regularity of breeding and milk production. But buffaloes are more hardy, easier to maintain, and their milk, with its higher fat content, is more acceptable in the market. Goats are cheaper in terms of capital investment and maintenance (see Science Today, July 1977, p. 26). More important, they can live off poor quality grass and scrubland; they do not raise the problem of converting cereal lands to fodder. Their maintenance increases the employment potential of the young in villages who graze them. These and many more questions need answers and, more important, concrete alternative courses of action.

S.J.

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SPECIAL CONCESSION FOR DEFENCE PERSONNEL

(Left) Bowstring-operated boring machine for preparing pearl necklaces. The year is 1390. Five years later (right), the artisan is using a *foot-operated* lathe, with bowstring and spring. (Illustrations from the Mendelschen Zwolf-Bruder-Stiftung)

ACADEMIC SCIENCE AND TECHNOLOGICAL CULTURE

SOME LESSONS FROM HISTORY

R. NARASIMHAN

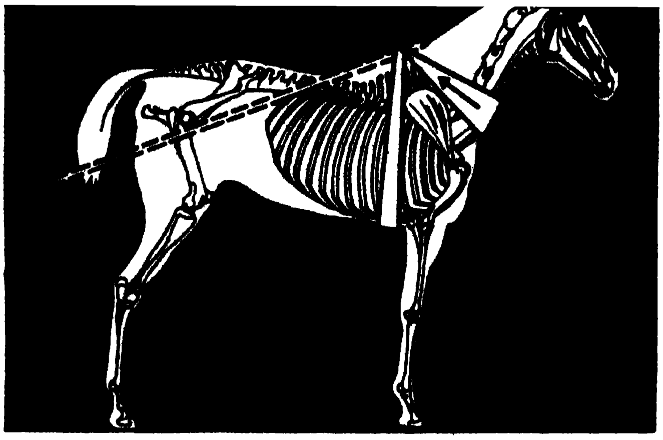
1. Does excellence in science lead to a technological culture?

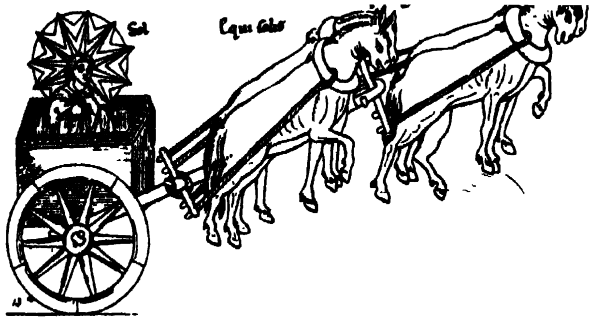
“It is well to observe the force and virtue and consequences of discoveries. These are to be seen nowhere more copiously than in those three which were unknown to the ancients, and of which the origin, though recent, is obscure and inglorious: namely, printing, gunpowder and the magnet. For these three have changed the whole face and state of things throughout the world, the first in literature, the second in warfare, the third in navigation, whence have followed innumerable changes: in so much, no empire, no sect, no star, seems to have exerted greater power and influence in human affairs than these mechanical discoveries.”

So wrote Francis Bacon in a much-quoted passage in his *Novum Organum* published in 1620. The origin of these three ‘ inglorious ’ discoveries is no longer so obscure, for, now, historians of technology generally agree that all these three came to Europe from the Far East, most likely from China. (It is significant that none of these three discoveries were known in India till relatively recently.) Printing was known in China already in the 10th century. All the Confucian classics were in print by AD 930. Interchangeable type was invented in the Far East in AD 1045 and metal types were in use in Korea by AD 1390. The earliest extant printed material based on moveable type in Europe, however, dates only from AD 1454. Similarly, gunpowder was in use in China in the 8th–9th centuries. Magnetic compass seems to have been in use in China almost a hundred years before it came to be known in Europe. Apart from these discoveries, the medieval side-harness for the horse that is claimed to have increased its pulling power by a factor of four or five was already known in China by the early Christian era. The modern saddle, stirrup and bridle, and the nailed horse-shoe, which were introduced into Europe in the 9th or 10th century, and which were instrumental in effecting far-reaching changes in the art of warfare, were in use in Mongolia even earlier. Although watermills were already in use in Roman times, the harnessing of windpower was unknown in Europe till much before the 12th century. But windmills were being used by the Arabs in the 7th century and their use very likely was known at still earlier times in some of the high plateaus of Iran. It is now believed that the Europeans acquired the windmill technology from the Arabs. The Arabs, very likely, were also instrumental in introducing paper into Europe. (The art of paper-making was known to the Chinese in the 2nd century AD.) There seems to be some reason to believe that even the gear-driven clocks invented in Europe in the 14th century were inspired by the complex, gear-driven, ‘ computing devices ’, like the astrolabe and the equatorium, which the Arab astronomers were using in the 11th and 12th centuries.

Apart from these technological innovations which Europe acquired from the Middle East and the Far East in early medieval times and later, much of the ‘ science ’ (Euclidean geometry, Aristotle’s natural philosophy) and ‘ engineering ’ (Archimedes, Vitruvius, Hero) of classical Greece and Rome was rediscovered around this time only through translations from Arab sources. Nevertheless, from these ‘ borrowed ’ beginnings in ‘ science ’ and ‘ technology ’, medieval Europe was able to forge, first a scientific revolution in about three to four hundred years, and subsequently, in less than another two hundred years, an industrial revolution.

Now, it is well-known that there was a strong base in the ‘ sciences ’ (in mathematics, astronomy and medicine) in India and China in medieval times. And, as we saw earlier, at least in China (and, possibly, to some extent in India also, although very little of the details of this is as yet known) there was an equally flourishing technological base. Yet, paradoxically, this highly





(Left) Ancient harness with neck and body girths. The illustration from *Histoire de la Locomotion Terrestre* shows how the neck girth pressed on the animal's windpipe. (Above) New medieval harness in drawing from Herrad von Landsberg, *Hortus Deliciarum*, early 13th century

developed, indigenous, intellectual and technological base in these countries of that time did not result in a scientific or industrial revolution comparable to the European one.

This strange state of affairs requires some explanation. What were the preconditions that existed in Western Europe that were missing in China and India, that in the one case technology and science could interact successfully, build on each other's strengths, and both move forward with explosive energy, while in the other case the condition of both science and technology at best remained stagnant and much of the time actually deteriorated?

Any plausible answer to this puzzle should be of more than academic interest. In fact, we can reformulate this puzzle in modern terminology by asking, " what is the relationship between ' academic science ' and technological culture? "

In countries like India (and the so-called third world countries), there is an obsessive pressure to transform the local societies to approximate the technological culture of the industrialised European and North American countries. Since the role of science in achieving this transformation is seen to be central and critical, it is taken to be axiomatically true that scientific excellence will automatically bring about a technological transformation. However, the historical evidence we have just been outlining would seem to directly contradict these beliefs.

The lesson we must draw from this contradiction is that we cannot expect to learn much about the true relationship between scientific and technological culture by studying the intimate relationship between science and technology that we see in the *current activities* of the technologically highly advanced countries. We must study the historical processes — the social and institutional forces — that were instrumental in bringing about the transformation in the technological culture of these societies that we see there today. In doing so, it is not the study of the history of science, per se, that is relevant, but the study of the history of technology and of the interaction between science and technology in the advancement of the latter.

Studies in the history of technology are of relatively recent origin and, unfortunately, the results of most of these studies are not readily accessible to the non-specialists. Thus, although many students of science have some knowledge of the history of science, most of them tend to know little of the history of technology. However, in the last decade or two several highly readable books and monographs on the history of technology in general, or one or more aspects of it in particular, have appeared. One of the more recent ones, and possibly also one of the best, is a book by Arnold Pacey, *The Maze of Ingenuity*. Also Musson and Robinson have published a collection of essays, *Science and Technology in the Industrial Revolution*. *A History of Western Technology* by Klemm contains excerpts from a variety of contemporary documents.

Even a cursory reading of these and similar works would make it abundantly clear that the development of a technological culture depends on a complex and intimate interaction *at the working level* between ' academics ' and ' mechanical artisans ' (interpreting both these terms in their widest senses). It is very rarely that these two roles are successfully combined in the same individual or in a group of individuals. Historically, one can identify a few such instances, especially in the formative stages of ' science ' and ' technology '. But most of the time, the interaction at the working level between concepts and ideas on the one hand, and implementations deriving from these on the other, have been predicated in an essential way on the availability of certain well-identifiable catalysing factors. I believe two of the most important of these have been: (1) a high regard for ' manual labour ' (broadly interpreted) in the community at large, the so-called ' work-ethic '; and (2) middlemen with a primary commitment to act as a bridge between the producers of ideas (concepts, theories, hypotheses, insights) and the producers of things (craftsmen, artisans, mechanics, and later on, industrialists and entrepreneurs). This bridge-building activity, historically, has found institutional manifestation in various forms: popularisation of ideas through publications of books, journals, encyclopædias, through lecture-demonstrations, through the organisation of schools outside the established educational system (' dissenters' academies '), and, finally, through ' philosophical clubs '.

In the rest of this article I would like to substantiate my thesis by considering the role of these two factors at two distinct periods in the development of Western technological culture: (1) at the time of the rapid technological transformation of Western Europe during the 12th and 13th centuries; and (2) at the time of the Industrial Revolution in England and America in the late 18th and 19th centuries.

2. ' Work-ethic and the mechanical arts

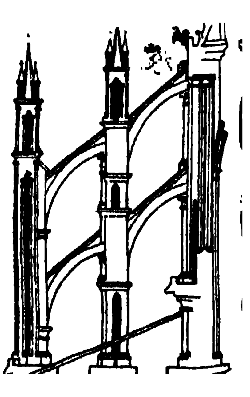
The controversial views of Weber, Tawney, and other sociologists and historians claiming a decisive role for the ' work-ethic ' of

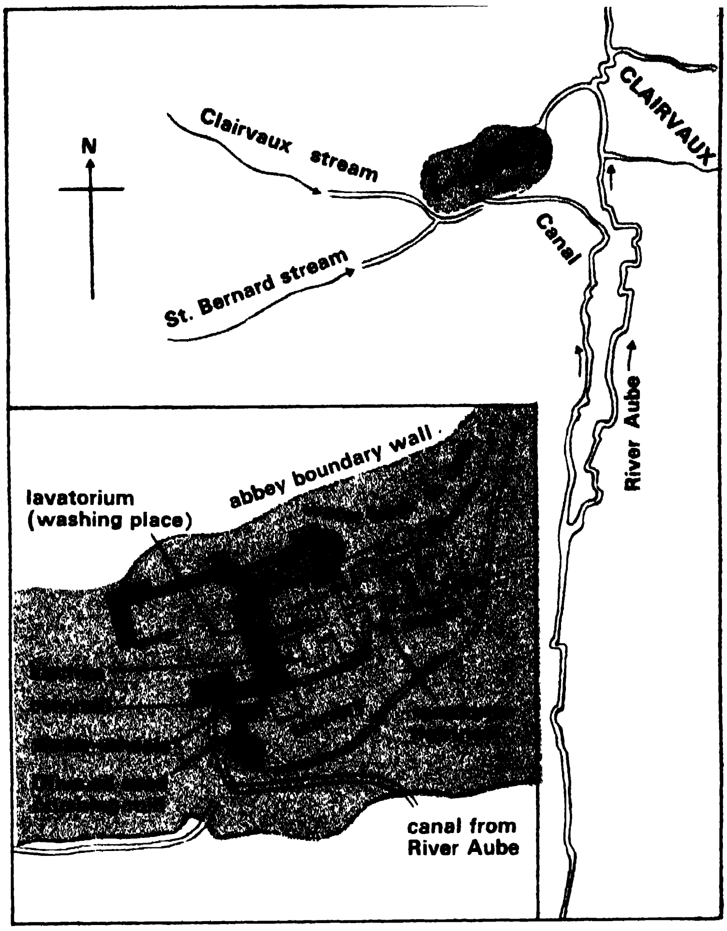
GEOMETRY AND THE GOTHIC

Gothic buttresses (13th century). (Drawing by Villard de Honnecourt)

Construction-lines for drawing a man's face (by Villard de Honnecourt, 1235)

Construction-lines used in designing the Westminster Abbey, 1245





Plan of Clairvaux Abbey and the water supply system developed by the Cistercian monks (AD 1136). The new buildings site (coloured portion) had been shifted about 400 metres away to the east from the original site so that water from the river Aube could be used (via canal) to supplement the flow from the two small streams

Protestantism and Puritanism in the economic growth of the West are well-known. However, Pacey points out that whatever factual truth there may be in these views, the emotional and religious commitment to the work-ethic did not certainly originate with Protestantism. Its roots go very much farther back. It was certainly revived by Martin Luther's doctrine of ' the priesthood of all believers', and provided a framework for initiating action at the level of the ordinary people. But the real origins of the work-ethic must be traced to the life-style for Christian monastic orders laid down by St. Benedict around AD 530. The Rule of St. Benedict prescribed five and a half hours of manual work each day for each monk, thus giving a religious sanctity to work of this nature. In the next 500 years, monastic life lost much of its discipline and religious fervour for manual work, till in the 11th and 12th centuries there was a great wave of enthusiasm to reform Benedictine monastic life and restore to it some of its original austerity. Several new monastic orders were formed, one of them being the Cistercians. This order grew into a highly dynamic community under the leadership of St. Bernard of Clairvaux.

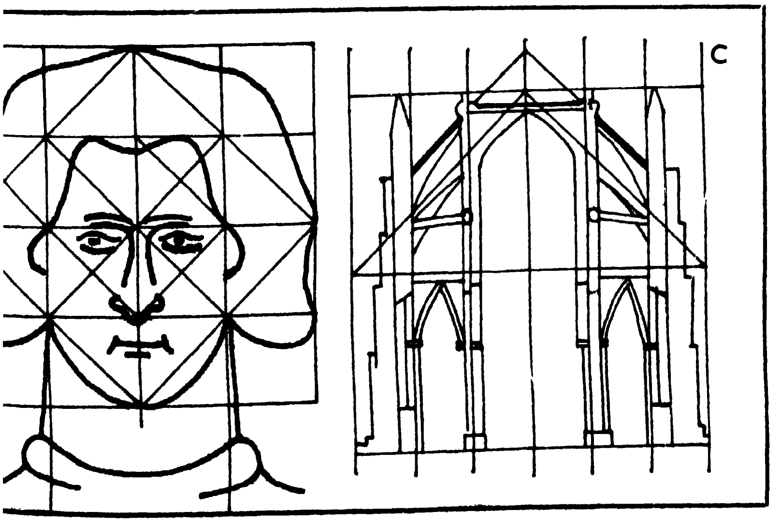
The Cistercian abbeys (there were more than 300 of them in Europe by the end of the 12th century) played a very important role in the development of craft technology and in the dissemination of technical information on a wide variety of mechanical arts all over Europe and England. Pacey points out that St. Bernard's revival of St. Benedict's emphasis on manual labour was of considerable importance in building up the technical competence of the Cistercians to a high level. In Pacey's words, St. Bernard taught that, " labour should play an important part in the life of a monk alongside intellectual effort and religious devotions. . . . Just as men had an obligation to think and pray, so also they had an obligation to do manual work. *It was perhaps natural in this context that monks should think about the techniques they used in the course of their work and endeavour to improve them* " (emphasis added).

The early innovations in the Gothic style of cathedral architecture (pointed arches, rib vaults, flying buttresses) were Cistercian in origin. Some of the more famous early cathedrals built incorporating this new building technology were: Abbey Church of St. Denis (1130–40), Canterbury Cathedral rebuilt in 1174, Notre Dame Cathedral begun in 1163. In the course of the next several decades, the high Gothic style became perfected resulting in such examples as: Chartres (1194), Rouen (1200), Rheims (1211), and later still, the rebuilt Westminster Abbey (1245) and Cologne Cathedral (1248).

The Cistercian monks in England played an important role in the revival of furnace techniques to smelt iron-ore and in the development of iron-making. In their abbeys they were highly innovative in harnessing water-power to carry out a variety of technical and domestic tasks. "At Clairvaux, for example, the river drove corn-mills, worked a fulling-mill and tannery and various crushing-mills, as well as supplying the kitchen and washing places, and flushing clean the latrines" [Pacey].

Agriculture was another area in which the Cistercian technical contribution was of a high order. They were instrumental in bringing vast areas of virgin land into cultivation since it was their practice to locate their abbeys far away from built-up areas and developed regions. In England, the growth of sheep-farming and wool-manufacture owed a great deal to Cistercian initiatives.

Unfortunately, the high religious emphasis placed on manual work in the early monastic orders slowly died down. Thomas Aquinas, in the 13th century, finally seems to have given a doctrinal sanction to devaluing manual work by the monks by arguing:

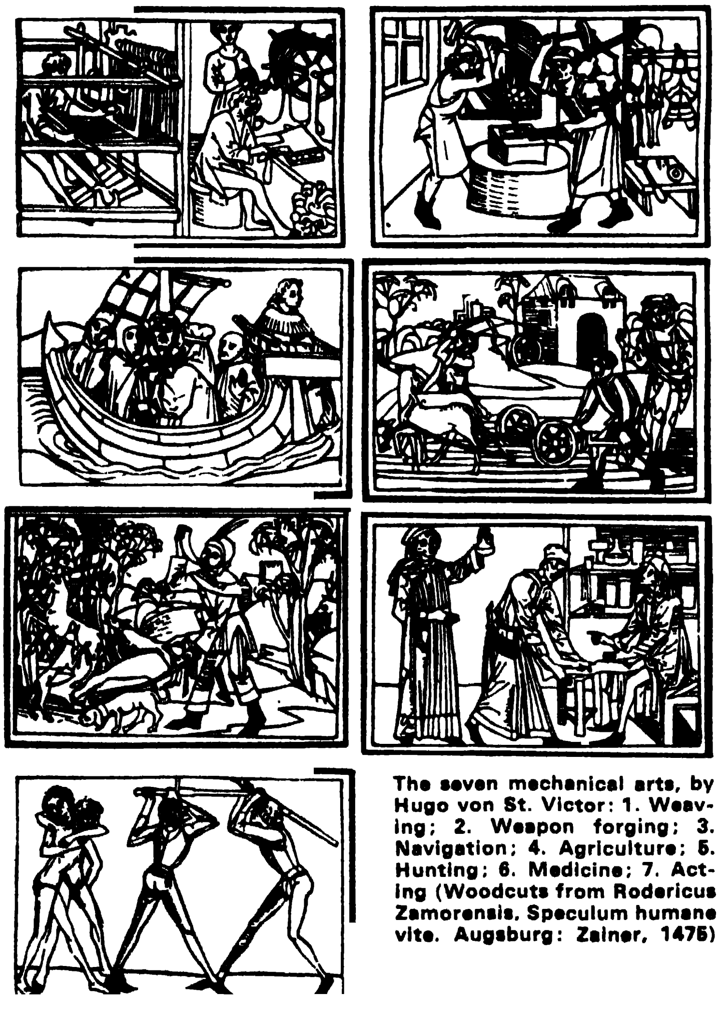


"If a man could support life without food, he would not find it necessary to work with his hands; the same applies to those who have other legitimate means of livelihood. In so far, however, as handwork is performed to overcome idleness or to mortify the body, it does not itself come within the scope of a command, since the body can be mortified and idleness can be overcome by many methods other than handwork. . . . If, therefore, nothing in their Rules enjoineth any special handwork, then are members of the Order no more bound to execute handwork than are those in the outside world" [from Klemm].

In the late 12th century, systematic efforts were made to teach the mechanical arts in the schools attached to the great cathedrals along with the Seven Liberal Arts inherited from the late Roman times. Hugh of St. Victor, a German who became the Director of the School of St. Victor in 1133, attempted to provide a 'theological' underpinning for the teaching of the mechanical arts by dividing them into seven branches: Weaving, Weapon-foundry, Navigation, Agriculture, Hunting, Medicine and Drama, and argued, "Of these, three are related to the external equipment of Nature, by which Nature protecteth herself against injuries; four are related to the inner equipment, that by nourishment and nurture she may grow and prosper. Thus there is a definite similarity to the Trivium and the Quadrivium; since the Trivium (Grammar, Dialectic and Rhetoric) is concerned with the designation of words, a somewhat superficial matter, while, on the contrary, the Quadrivium (Arithmetic, Geometry, Astronomy and Music) deals with ideas which are inwardly grasped. . . " [from Klemm].

An important factor in the development of the mechanical arts in the 12th and 13th centuries was the high regard given to mathematics. At the school attached to the Chartres Cathedral, the great interest taken in Plato's works was a direct stimulus to the teaching of mathematics. The great age of Gothic architecture coincided with the rediscovery of Euclid's geometry in Latin translation from Arab sources. Euclid's theorems were first taught at the Chartres school.

These Cathedral schools, from which the universities evolved later, often enrolled young persons who were training themselves to become skilled craftsmen. Pacey writes: "Such were the architects of the cathedrals — literate men who knew Latin and who were capable of keeping in touch with academic geometry; they were the men who could write about mensuration and surveying. One anonymous French author of the 13th century described methods used by masons for finding the areas of triangles, octagons, and circles." It has been argued by historians of cathedral architecture that the spatial proportions of the great Gothic cathedrals were worked out using geometric constructions.


The seven mechanical arts, by Hugo von St. Victor: 1. Weaving; 2. Weapon forging; 3. Navigation; 4. Agriculture; 5. Hunting; 6. Medicine; 7. Acting (Woodcuts from Rodericus Zamorensis, Speculum humane vite. Augsburg: Zainer, 1476)

The two centuries from 1150–1350 saw a very rapid growth of technology in Western Europe and, as we have seen, the monastic orders and, later, the cathedral schools played a decisive role in building up this technological base. The next hundred years were lean ones for Europe as far as technological innovations were concerned. From 1450 onwards again, with the start of the Renaissance, scientific and technical activity began to gather momentum. But now the impetus for discovery and innovation was provided increasingly by public works, trade and commerce, and State patronage. It was in the late 17th and the 18th centuries that we find again a great enthusiasm for democratic reforms in the educational sphere to bring together the academicians and artificers. The effects of this move are most persuasively seen in the Industrial Revolution in England.

3. Science and technology in the Industrial Revolution

"A revolution in the method of production in one sphere of industry involves a similar revolutionary change in every sphere. . . . Thus, machine spinning made machine weaving necessary; and both together necessitated a mechanical and chemical revolution in bleaching, printing, and dyeing. In like manner, on the other hand, the revolution in cotton spinning made essential the discovery of the cotton gin for the separation of the seeds from the cotton fibre, for only then could the production of cotton reach the proportions which were now indispensable. The revolution in the method of production in industry and agriculture likewise necessitated a revolution . . . in the means of communications and transport . . . by a system of river steamships, railways, ocean steamships, and telegraphs. . . . But, now, vast quantities of iron had to be welded, cut, bored and shaped. For this, in turn, huge machines were required. . . . The machine itself had to produce machines by machines. . . . The most essential condition [to accomplish this] was a machine to supply power to any extent and under perfect control. This already existed in the steam engine. But it was still necessary to gain the power of producing by machinery the perfectly accurate geometric forms required for the separate parts of machines: straight lines, planes, circles, cylinders, cones and spheres. This problem was solved by Henry Maudsley in the opening years of the 19th century by the invention of the slide-rest. . . . This mechanical appliance does not replace another tool, but the human hand itself. . . . Thus, it became possible to produce the geometrical forms requisite for the individual parts of machinery with the degree of accuracy, ease and speed that no accumulated experience in the hand of the most skilled workman could give. . . . "

Thus, Karl Marx perceptively analysed the revolutionary aspect of the Industrial Revolution. A consideration of the conceptual aspects of the technological changes that were taking place at this time would show that in the Industrial Revolution we see the first beginnings of the transformation of artisan-based technology to science-based technology. In this sense, it is the start of the modern era when technology increasingly tends to derive directly from academic science. It should be of interest, then, to ask what were the relative roles played by the artisans and the academics in bringing about the Industrial Revolution? Contrary to what we might have been led to believe on the basis of our modern prejudices, historical studies tend to show that the initiative for effecting this transformation from artisan-based to science-based technology did not originate from academic scientists but from artisan-engineers and engineer-entrepreneurs, who had sufficient understanding of science and who were keenly aware of the relevance of science to bring about this change. Our immediate concern, here, is with the social and institutional forces that were responsible for the diffusion of scientific knowledge to these non-academic 'fabricators and implementors'.

Let us first consider briefly the professional and intellectual backgrounds of some of the individuals who were directly responsible for the revolutionary technological changes that Marx mentions in his analysis.

The Newcomen engine which was the direct ancestor to Watt's steam engine was invented around 1695–1700 by Thomas Newcomen, an ironmonger and blacksmith, and John Cawley, a plumber. Their design was based on earlier work done by von Guericke in Germany, and by Huygens and Papin in Paris. There has been much speculation about how Newcomen knew about these results and whether he knew about them at all. It is known that Newcomen used to correspond with the members of the Royal Society in London, especially with Robert Hooke. It is presumed that either from these or other private sources he might have kept himself well-informed about developments in this area.

Smithy with water-driven hammers (Woodcut from Spechtshart, Flores Musicae, Strassburg, J. Pruss 1488)

James Watt was the son of a carpenter and merchant, and was educated at the local grammar school where he showed a talent for mathematics. After working for some years as an apprentice to his father, he came under the influence of Dr. Joseph Black of Glasgow University, who was the inventor of the concept of latent heat and was one of the most renowned chemists of his day. Later, when Watt shifted to Birmingham, he came into close contact with many of the distinguished scientists of that time. He helped Joseph Priestley in his experiments leading to the discovery of the constitution of water.

Some of the individuals involved in the mechanisation of the textile industry were self-taught, while some of the others, although closer to the intellectual society of their days, worked closely with skilled mechanics in transforming their ideas into hardware. Samuel Crompton who invented the mule was the son of a skilled craftsman and taught himself mathematics by attending evening classes. Eli Whitney, an American, who invented the cotton gin, was educated at Yale and was part of the intellectual society of New England of his day. He is best known as the inventor of mass production techniques based on interchangeable parts. Dr. Edmund Cartwright, the inventor of the powerloom, was a Fellow of Magdalene College, Oxford. Lacking any knowledge of machinery, it is said, he sought the assistance of experienced workmen to translate his ideas into a reasonable working model.

Henry Maudsley started work in 1783 at the age of 12. Aside from his accomplishments in machine tool technology, he was keenly interested in science. Astronomy and making of telescopes for his own use were his hobbies. He was a close friend of Faraday who used to visit his works frequently.

Not only many of the inventors but many of the scientists of the 19th century were also self-taught. This was true of Faraday, Wheatstone and Davy, among others. Self-education was a highly valued virtue in that age and abundant facilities existed to improve one's scientific, intellectual and professional background, if one wanted to.

Mechanics' institutes or similar organisations were common and books enjoyed very wide sales. Much of the scientific knowledge that had been accumulated by men like Faraday, Helmholtz, Henry, Davy, Black, Priestley, Dalton, and others, were readily accessible to the general public. (Faraday's book *Electrical Researches* was the bible of Edison during his early years.)

For the more professionally inclined, science periodicals were available. The Royal Society began to issue its *Philosophical Transactions* in 1665 providing a source of information on the work of the leading British scientists. In America, the first scientific periodical seems to have been the *Transactions of the American Philosophical Society* which began publication in 1771.

There were many organised and individual efforts at popularising science. Benjamin Thompson, Count Rumford, floated a proposal in 1799 to found a public institution by subscription " in the metropolis of the British Empire for diffusing the knowledge, and facilitating the general introduction, of useful mechanical inventions and improvements ". The result was the Royal Institution which, from 1851 onwards, has been arranging science lectures with demonstrations for the general public. In the United States, the Franklin Institute was founded in 1824 and the Smithsonian Institution in 1846. The Franklin Institute was intended to be a meeting place for tradesmen, businessmen, and scientists, to discuss the practical applications of science and to encourage science by making awards to inventors.

Many popular science journals were started in this era: for example, in England, *Nicholson's Journal* and

Mechanics' Magazine. The Engineer was founded in 1856. Professor Silliman of Yale started the *American Journal of Science* in 1818 which was the first national science journal in America. Its object was to provide general scientific information for the use of scientists and others. By its influence in the era leading up to the Civil War, it did much to assist the growth of American science. The *Popular Science Monthly* was founded in 1872 and was widely read by amateur inventors who thrived during and after the Civil War.

Apart from the variety of books on several specific subjects, many encyclopaedias and dictionaries were published at this time. These discussed mechanical processes and machines, often illustrating them with drawings. These were often published in parts so that they could be within the financial means of the artisans for whom they were intended.

To those who could not afford to buy these publications, there were the public libraries. Chetham's Library in Manchester was started in 1653 and Dalton found this library of great assistance in his work. A subscription library was founded in 1792 by the Manchester Reading Society.

Again, in the second half of the 18th century, in England, popular science lectures given by itinerant lecturers — some nationally famous — were very common. The contribution of these itinerant lecturers to the diffusion of general scientific knowledge in the country has not yet been fully appraised. Several of these lecturers took with them on their tours quite elaborate working models and scientific apparatuses for demonstration. In addition, they usually published their lectures in book form or at least printed and sold synopses of their lectures. These were priced so as to be readily accessible to the ordinary public, mechanics and other artisans.

Many of these itinerant lecturers kept closely in touch with the researches of the best scientists of their day, and were outstanding popularisers of science. From available historical records it can be ascertained that in their popular lectures they covered topics such as: the nature of matter, laws of motion, mechanics, projectiles and pendulums, hydraulics, pneumatics, heat, pyrometry, optics, light, colour and astronomy.

These itinerant lecturers were varied in their educational backgrounds. Some were almost wholly self-educated. Several others had degrees from Scottish universities where scientific work was most thriving at that time. Musson and Robinson, from whose book many of these details have been taken, quote Dr. Brewster, a biographer of James Ferguson, one of the successful itinerant lecturers, as saying that to the lectures of Ferguson and others like him " we must attribute the general diffusion of scientific knowledge among the practical mechanics of this country, which has in a great measure banished those antiquated prejudices, and erroneous maxims of construction that perpetually misled the unlettered artisan ". Dr. Brewster also noted that Ferguson's books " were widely circulated among all ranks of the community. We perceive them in the workshop of every mechanic".

Another characteristic feature of the late 18th and early 19th centuries in England and America was the large number of Literary and Philosophical Societies (' Philosophical Clubs ') that grew up and thrived not only in national capitals like London and Philadelphia, but in numerous provincial towns like Manchester, Birmingham, Leeds, Newcastle, Norwich, Derby, and in America, Boston and New Haven. It is only in recent years that historians of technology have begun to study systematically the constitution and activities of these Philosophical Societies. One of the most famous and most influential of these Societies was the Lunar Society of Birmingham. To understand the role played by these informal gatherings in the diffusion of scientific knowledge in the 18th and 19th centuries, it is perhaps useful to consider the activities of the Lunar Society briefly.

The Society met every month on the Monday nearest the full Moon (and hence the name Lunar Society). It kept no record of its deliberations, nor did it publish any proceedings of its activities. (The activities of the Society have been reconstructed by historians from indirect sources like letters, memoirs and so forth.)

The membership of the Lunar Society included: Mathew Boulton, Josiah Wedgwood and James Keir who were three of the most successful industrialists of that age; R. L. Edgeworth, a well-known educationist; Thomas Day, a very successful children's book writer; Erasmus Darwin, the grandfather of Charles Darwin and a botanist; James Watt, the most famous engineer of the Industrial Revolution; and Joseph Priestley, one of the most renowned scientists of that time.

The Society flourished from about 1770 to the end of that century. The intellectual and practical interests of the members of the Lunar Society seems to have ranged over the entire spectrum of problems and potentialities of industrialisation: " transportation, finance, supply of power and raw materials, education, politics, community improvement and business organisation. . . . The most characteristic function of the Society, however, was the combination of technological innovation with scientific investigation. . . . The Lunar Society constituted an informal industrial research establishment in which science and technology were regularly and deliberately cross fertilised " [Schofield].

Studies of the activities of the Lunar Society and similar societies that grew up and thrived influentially in the midlands and northern towns of England show that the interaction between scientists, technologists, engineers and industrialists played a significant role in bringing about the changes in the structure and functioning of society which in their totality amounted to the Industrial Revolution.

There was much interaction between visiting Americans and members of some of the philosophical societies of England. Benjamin Franklin, for example, was a good and close friend of the Lunar Society members. Franklin was one of the founders of the American Philosophical Society in Philadelphia in 1743. After the Revolutionary War, Franklin assisted in constructing a permanent hall for the Society and acted as its president till his death. After the Revolutionary War, Academies of Arts and Sciences were founded in many cities in America ; those in Boston and in New Haven, founded in the late 18th century, were perhaps the most important of these.

4. Relevance of history to current problems

The work-ethic of the 11th and 12th century monastic orders — Cistercians, in particular — and the historical details about the diffusion of science among the artisan-engineers and entrepreneurs during the Industrial Revolution bear out, I think, rather convincingly my earlier-outlined thesis that the development of a technological culture is decisively dependent on a complex and intimate relationship at the working-level between ' thinkers ' and ' fabricators ' or ' implementors '. And in promoting this relationship, a high regard in the society for ' manual work ' and the role of middlemen functioning as bridge-builders between these two groups are of fundamental importance.

In India, typically, both these factors have been non-existent. And, if my thesis is valid, that could to a large extent explain the puzzle we started out with. Analogous explanations could hold for China, although

Organised R & D and Independent Inventors

In the 20th century technological innovation intimately depends on scientific sophistication of a very high order. Because of this, one may be tempted to assume that the lessons of history are not of immediate relevance. But there is no justification for such an assumption. Despite the efforts to organise and systematise the process of making inventions through the establishment of large industrial and governmental R & D laboratories, studies of inventions show clearly that the independent inventor, working outside the framework of established laboratories, still plays a seminal role. Studies of various major 20th century inventions indicate that only a small proportion of these came from laboratories of large corporations.

J. Jewkes and his colleagues in their important, and by now classical, study, *The Sources of Invention*, have considered in detail the origins of 63 important inventions of the recent past. They have determined that over one-half of these were the result of pioneering work carried out by individuals with little or no institutional support. In this category come the following cases: Air Conditioning; Air Cushion Vehicles; Automatic Transmissions; Bakelite; Ball-point Pen; Catalytic Cracking of Petroleum; 'Cellophane'; Chromium Plating; Cinerama; Cotton Picker; Cyclotron; Domestic Gas Refrigeration; Electric Precipitation; Electron Microscope; Gyro-compass; Hardening of Liquid Fats; Helicopter; Insulin; Jet Engine; Kodachrome; Magnetic Recording; Moulton Bicycle; Penicillin; Photo-typesetting; 'Polaroid' Land Camera; Power Steering; Quick Freezing; Radio; Rhesus Haemolytic Disease Treatment; Safety Razor; Self-winding Wristwatch; Streptomycin; Sulzer Loom; Synthetic Light Polariser; Titanium; Wankel Engine; Xerography; Zip Fastener.

Innovations that have come out of the efforts of industrial research laboratories are: Acrylic Fibres; 'Cellophane' Tape; Chlordane, Aldrin and Dieldrin; Continuous Hot-strip Rolling; Crease-resisting Fabrics; DDT; *Diesel-electric Locomotive;* Duco Lacquers; *Float Glass;* Fluorescent Lighting; *Freon Refrigerants; Methyl Methacrylate Polymers;* Modern Artificial Lighting; *Neoprene; Nylon;* Oxygen Steel-making; *Polyethylene; Semi-synthetic Penicillins; Silicones;* Synthetic Detergents; *Television;* Terylene; *Tetraethyl Lead; Transistor.* The italicised inventions either originated or were developed for commercial exploitation in really large industrial laboratories. The rest were from much smaller firms.

Jewkes et al note that "even where inventions have arisen in the research laboratories of large firms, the team responsible for it seems often to have been quite small. It is usually found that one outstanding figure has been surrounded by, and has stimulated, a few devoted colleagues in an intimate relationship with his manner of thought and speculations".

These findings would seem to indicate that one does not have to go to the distant past to learn from history.

R. N.

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the issues involved there might be more complex. In any case, my principal objective is not so much to worry about the absence of these factors in historical times in India, but to voice my concern about their continued absence now.

I think it is important for us today to learn from history that technological revolutions are brought about, not by academic scientists, but by artisan-engineers and engineer-entrepreneurs. Quite often these innovating individuals are non-conformists and dissenters. And it is important to make available means for such persons to acquire scientific and technological knowledge through informal and semi-formal channels. Academic scientists can and must play a significant role in catalysing the innovative potentialities of these individuals. Frameworks for informal and semi-formal diffusion of scientific and technological principles and practices are as important as, and in some cases perhaps more important than, frameworks for formal science education in the third world countries which are concerned about industrialising and technologically revolutionising their societies.

It is significant to observe that in the way educational and extra-curricular/professional interactions are structured at present in our country, we do not have the equivalents of either the 'dissenters' academies' or the 'philosophical clubs'. Academicians hardly ever come into intellectual contact with artisans; nor do they come into intellectual contact with non-academic innovators in industry and other implementation-oriented spheres. Part of this problem stems from our highly class-conscious social structure. Part of this problem also stems from the fact that the institutionalisation of academic science in our country is patterned after that prevailing in the West *now* rather than in the 17th or 18th centuries. On the other hand, the technological culture of our country at present is possibly less sophisticated than what was the case in the West in the 17th and 18th centuries. This mismatch in the science and technology background between the academic and artisan/entrepreneurial cultures tends to push apart, rather than pull together, 'academicians' and 'fabricator-implementors'. I think this points out the urgent need for bridge-builders, bridge-building activities and bridge-building institutions. History can certainly teach us what is possible to accomplish in this area.

The spirit in which this article has been written is very aptly summarised by some remarks attributed to Sir Alex Smith, Director of the Manchester Polytechnic. He is reported to have suggested that the expansion of full-time degree courses and economic decline in the UK, while not necessarily connected, could be attributed to the same underlying cause:

> "to the lack of esteem given to skills in doing, making, designing, developing and manufacturing, compared with the high esteem given to academic study and scholarship, to analysis and to research as the proper pursuit of the ablest minds. We have created two cultures, not so much in the sense that [C.P.] Snow outlined, but in the sense that cultured, civilised, educated, research-minded people pursue a cultured, civilised, educated, research-minded life, while the process of earning our livelihood as a nation can be carried out by 'others'. It is not a very edifying or stable division."

A Senior Professor at the Tata Institute of Fundamental Research and Director of the National Centre for Software Development and Computing Techniques (at the TIFR), Prof. Narasimhan (51) did his MS in electrical engineering from the California Institute of Technology, Pasadena, USA, and both his MA and Ph D in mathematics from the Indiana University, USA. A computer scientist, his research interests include visual data processing, programming language theory, models of language behaviour and application of system-theoretic concepts and techniques to the study of behaviour and behavioural sciences. Fellow of the Indian Academy of Sciences and also the Indian National Science Academy, he was also awarded the Jawaharlal Nehru Fellowship for 1971–73. *Recommends reading:* **1.** Klemm, Friedrich 1954/1959 *A History of Western Technology*. George Allen & Unwin. **2.** Voice of America Forum Lectures 1968. *History of Science*. Higginbothams, Madras (for R. E. Schofield). **3.** Jewkes, J. et al 1969 *The Sources of Invention*. MacMillan. **4.** Musson, A. E. & Robinson, E. 1969 *Science and Technology in the Industrial Revolution*. Univ. Toronto Press. **5.** Pacey, Arnold 1976 *The Maze of Ingenuity, Ideas and Idealism in the Development of Technology*. MIT Press. **6.** Wilby, Peter 1976 The outdated university tradition, *New Statesman* (21 May) (for Sir Alex Smith).

OF VIRUSES AND JAUNDICE

M. V. N. SHIRODKAR
N. G. CHANDERKAR

And David's Lips are lock't; but in divine
High piping, Pehlevi, with "Wine! Wine! Wine!
Red Wine!"—the Nightingale cries to the Rose
That yellow Cheek of hers to 'incarnadine...

Yellow cheeks had been known to represent illness long before Omar Khayyám wrote those lines, but the twentieth century reader could read an irony in that eleventh century quatrain: that alcohol, taken in moderation, may lend a healthy suffusion of pink to one's cheeks, but consumed *ad libitum*, it can lead to hepatitis or inflammation of the liver (or even cirrhosis), and hepatitis can bring that sickening yellow colour to the skin and the whites of one's eyes. We call it jaundice.

The term jaundice comes from 'jaune', the French word for yellow; the scientific name is 'icterus'. It is a characteristic lemon-yellow pigmentation of the bodily tissues, especially of the sclerae (the whites of the eyes), due to excessive accumulation of bilirubin, or bile pigment, in the serum. Bilirubin is produced from the breakdown of haemoglobin of the blood in the reticuloendothelial system. This system comprises the phagocytic elements of the liver, spleen and bone marrow. These phagocytic cells engulf and break down the worn out or diseased red blood cells in the body. When produced in normal amounts, bilirubin is discharged into the blood and excreted by the liver. Now, if the rate of excretion fails to match that of pigment production, bilirubin accumulates in the serum and, ultimately, stains the tissues, giving rise to clinically apparent jaundice.

What causes jaundice? It must be made clear that jaundice is a sign. Its origin can be compartmentalised, according to location, as *hepatic, post-hepatic*, or *pre-hepatic*; at the same time, to simplify, we could also classify the causative agents as physical, chemical and biological.

In hepatic jaundice, the liver cells themselves cannot competently excrete the bilirubin, which is being produced at a normal rate. This occurs in the case of the 'biological' causes like viruses and the 'chemical ones' like the toxic action of drugs such as alcohol or chloroform which damage the liver cells, lead to inflammation and interference with the normal bilirubin excretory function of these cells and, thus, to jaundice. The well-known role of excessive alcohol consumption in repeated liver cell destruction and scar-formation (cirrhosis) is a case in point.

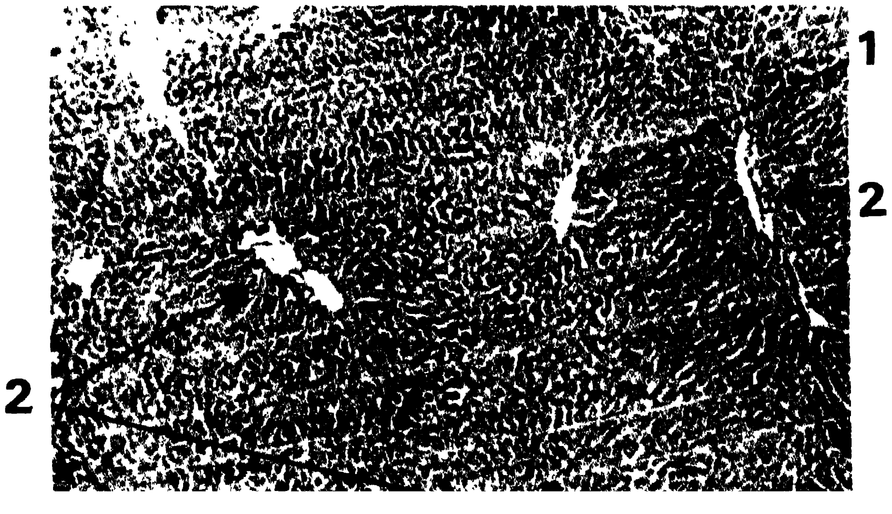
In post-hepatic jaundice, there is mechanical obstruction to the passage of bile through the biliary transport apparatus. An example of such a 'physical' category is obstructive jaundice, which may be produced by a tumour of the head of the pancreas, or by a stone in the bile duct, which impedes the normal flow of bile from the gall bladder into the duodenum. Should the impediment be serious, the bile will 'back up' into the circulation and the excess bile pigment produce jaundice.

In pre-hepatic jaundice, the excretion of bilirubin by the liver is normal, but the *production* of bilirubin is excessive, over and above the capacity of the liver to excrete it. Examples of jaundice, due to excessive bilirubin production following excessive haemoglobin breakdown, are the various haemolytic anaemias, but, in particular, a condition called neonatal jaundice (see box on p. 22).

The normal human liver — microscopically

The microscopic, routinely visualised structure of the normal human liver (Fig. 1) is as follows the histological unit is a lobule consisting of liver cells (hepatocytes) which make up the parenchyma which carries out the normal hepatic functions. The liver is made up of innumerable such lobules, separated from one another by delicate fibrous strands. At the centre of each lobule lies the central vein, a branch of the hepatic vein, whilst at the periphery, lying within the fibrous strands, are a few portal triads. Each triad consists of an arteriole (a branch of the hepatic artery), a vein (a branch of the portal vein) and a biliary ductule. The hepatocytes are arranged in plates one cell thick. These radiate from the central vein to the periphery of the lobule, constituted by the portal triads; the plates form an intricate labyrinth, the space of which is occupied by thin-walled blood-carrying channels called sinusoids. These are lined by large phagocytic cells belonging to the reticuloendothelial system and called the Kupffer cells. The sinusoids drain blood from the portal vein and the hepatic artery into the central vein. The bile secreted by the liver cells is carried by means of a series of very tiny channels, known as bile canaliculi, to the periphery of the lobule and drain via the biliary ductules into the bile duct. To maintain the structural integrity of the parenchyma, the cells have to be anchored to a scaffolding known as the reticulum which is made up of a fibrous protein called reticulin. This cannot be seen in the normal routine liver section because it does not take up the usual stain.

Fig. 1 Photomicrograph of normal human liver (x84). A typical liver lobule can be seen. Arrow 1 shows a central vein, while arrows 2 show the portal triads which partially limit the liver lobule. Radial arrangement of liver cell (parenchymatous) cords, separated by sinusoids can be clearly seen



Infective hepatitis

When it comes to the biological causes, the most important causative agents behind hepatitis (and hence jaundice) are viruses. And that brings us to the most common form of this disease — *infective hepatitis.* In this context, clinicians choose to differentiate between 'infective hepatitis' and 'viral hepatitis', the former being a wider term, encompassing not only viruses, but also all *other* biological causative agents.

Viral hepatitis is caused by at least two small viruses — A and B, and in restricted localities, the C virus. The C type of hepatitis has recently been recognised as being clinically indistinguishable from A or B, but immunologically different. In some areas of the world, it is now the most common form of hepatitis *following blood transfusion.* The predominant manifestation in these viral forms is hepatocellular necrosis which means death of liver cells. The other viruses which are known to produce hepatitis in the neonatal and perinatal periods are rubella (German measles), cytomegalovirus, herpes simplex, chickenpox, influenza, measles and smallpox.

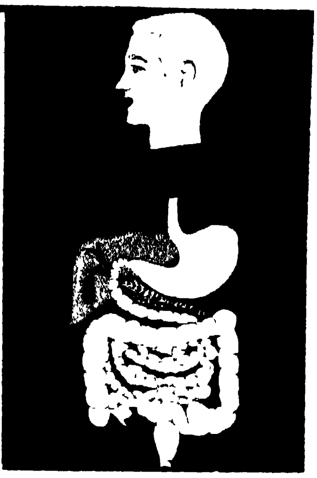
Besides viruses, two prominent causative agents behind infective hepatitis are bacteria and protozoa. An example of bacterial hepatitis is leptospirosis, or Weil's disease (the disease is caused by a spirochaete, *Leptospira icterohaemorrhagiae*, and is transmitted through the urine of an infected rat). Congenital infection with *Treponema pallidum*, the spirochaete of syphilis, can also produce jaundice in the neonate. Examples of protozoan hepatitis agents are *Toxoplasma* and *Entamoeba histolytica. Toxoplasma* is an intra-cellular parasite which can cross the placenta and produce neonatal jaundice. *E. histolytica* can produce jaundice following hepatitis in cases of amoebiasis.

In this article, we shall discuss mainly the viral aspect of hepatitis, an area in which much of the research work is concentrated.

It must be made clear at the outset that, in cases of viral hepatitis, by no means do all patients develop the lemon-yellow tint of the sclerae — the visible sign of jaundice. For every proven case of jaundice, there are 10 to 20 'carriers' who have non-apparent or subclinical infection and it is these people who pose a greater danger to public health, being the potential foci of spread of the virus.

To come back to the patient, he may give a history of contact with another jaundiced patient, or with rats, or admit to addiction to drugs or alcohol. Actually, the patient's intake of alcohol should be very carefully looked into since, as Fig. 2 shows, infective hepatitis can cause greater damage to the liver which has already been damaged by alcoholism. And, travel experience must also be looked into, as certain areas of the world have a very marked incidence of either hepatitis A, B or C or some of the other viruses, such as yellow fever in South America and Africa. (Why it should be so is still an interesting research problem!)

COMPARTMENTALISATION OF JAUNDICE ACCORDING TO LOCATION & CAUSATIVE AGENT



I HEPATIC JAUNDICE

1 Biological Agents

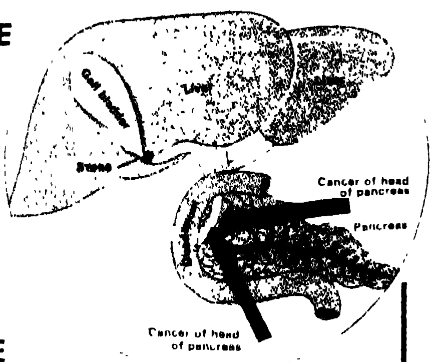
- **Viruses (Hepatitis A, B, and others)**
- **Bacteria**
- **Protozoa**

2 Physical Agents

- **Accidental damage to liver**
- **Irradiation damage during radiotherapy**

3 Chemical Agents

- **Alcohol**
- **Chloroform**
- **Carbon tetrachloride**
- **Other drugs**
- **Phosphorus poisoning**


Obstructive Jaundice

II POST-HEPATIC JAUNDICE (Obstruction)

- **Stone in biliary tract (bile duct)**
- **Carcinoma (cancer) of head of pancreas**
- **Primary carcinoma of liver**
- **Physiological jaundice of newborn**

III PRE-HEPATIC JAUNDICE (Haemolytic Anaemias)

- **Blood-group incompatibility (Rh, ABO)**
- **Glucose-6-phosphate dehydrogenase deficiency**
- **Other (rare) genetic-based conditions**

Normal concentrations of serum bilirubin range from 0·5 to 1·2 mg/100 ml and all the bilirubin is in the free form. By free, or unconjugated, bilirubin we mean the form released by the haemoglobin breakdown; it is less water-soluble and circulates tightly bound to serum albumin. Conjugated bilirubin, on the other hand, is esterified, which means a salt formed with two molecules of glucuronic acid on the propionic acid side-chains, and this is more water-soluble. When a high proportion of bilirubin is in the conjugated form, jaundice is detectable at levels of 2-3 mg/100 ml, for this form of the pigment stains the superficial tissues of the body, such as the sclerae and the skin, much more readily than does free bilirubin.

As regards the clinical picture, both in hepatitis A and B, the symptoms are very similar, but more serious in the latter infection. In the usual, clinical form, acute hepatitis resembles flu. In most patients, the pre-jaundice stage lasts three to nine days; the striking features are loss of appetite (anorexia), and dislike towards foods and cigarettes, or *bidis.* Nausea, or even actual vomiting, may occur in the pre-jaundice phase for about three to four days and a dull ache, or pain, under the right rib margin may be felt. A fever of 37·6°–39·4°C may last for two to five days; chills rarely accompany the fever, which subsides with the appearance of jaundice. Skin rashes appear in about five per cent of the cases, especially with hepatitis B, along with joint and muscle pains. Very rarely would a physician consider a diagnosis of viral hepatitis, except in known epidemics, prior to the appearance of the amber-coloured urine. Soon after this stage, the jaundice phase begins, to last for about one to two weeks; further darkening of urine and constipation along with pale-coloured stools occur.

Within a few (8–10) days of the onset of jaundice, the symptoms abate, appetite returns and abdominal discomfort and vomiting cease, pale stools regain their normal colour and jaundice gradually clears. The convalescence phase may last between two to six weeks; general weakness and fatigue may persist longer.

In general, the great majority of the cases recover. The mortality figures range from 0·1 to 1·0 per cent in the case of hepatitis A, and from 1·0 to 10·0 per cent in hepatitis B (the higher mortality figure is seen in cases of hepatitis following blood transfusions). Also, hepatitis B, particularly, may be followed by sequelae, such as subacute hepatitis, chronic active hepatitis which may progress to post-hepatitic cirrhosis, or even to primary carcinoma — in as many as 10 per cent of the affected cases.

In the case of hepatitis A, the incubation period is two to six weeks. The virus enters the body — usually by the oral route — and probably multiplies in the intestinal lining epithelium before spreading through the blood stream to the liver parenchyma. It can be detected in the blood and faeces a week before the onset of jaundice — this is the period when the patient is most infectious for others — and usually disappears after the serum transaminase levels reach their peak.

In hepatitis B, the virus usually enters the body by artificial inoculation of infected human serum (as well as by other routes). The incubation period is longer (six to 24 weeks). The most striking feature of hepatitis B virus is that, in a small proportion of cases, it persists in the serum for months or years, *despite apparent recovery*.

Fig. 2 shows necrosis (cell death) of liver parenchyma in liver biopsy in acute hepatitis A, or B. Usually, one sees focal necrosis within the liver lobule, with characteristic " ballooning " of liver cells, and infiltration by inflammatory cells around the portal triads. In rare cases, a fulminating hepatitis develops and, within days, kills the patient through acute yellow atrophy (massive cell death). In the great majority of acute cases, however, recovery occurs and parenchymal regeneration is completed within three months — the liver cells have extraordinary regenerative powers!

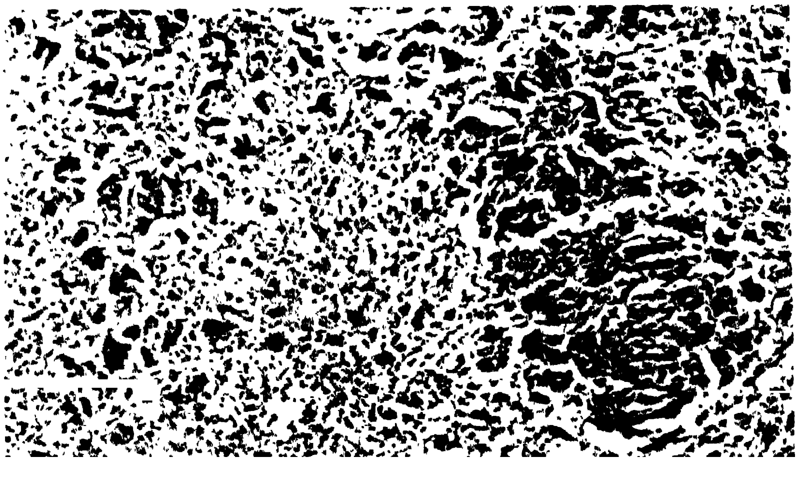
An attack of hepatitis A generally confers long-lasting immunity; however, *second* attacks have been seen in about five per cent of patients, for reasons not yet clear to us. It should be noted here that there is no cross-immunity between hepatitis A and B. Resistance to hepatitis A and B varies and is particularly low in pregnant and menopausal ladies, in older persons, and, in the higher socioeconomic groups.

How the viruses spread

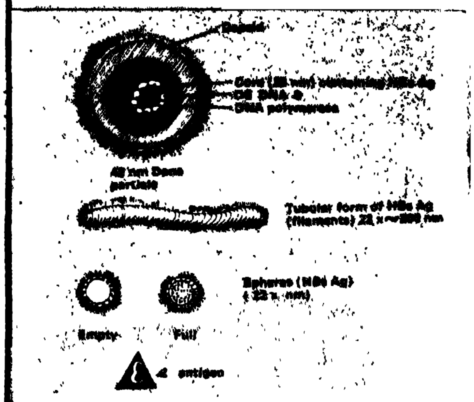
The epidemiology, or mode of spread, of hepatitis A and B viruses has several interesting aspects for the researcher. Both forms of the disease display a worldwide distribution, though the exact incidence is difficult to assess, because of widely differing surveillance methods. Epidemics of hepatitis A have been described in most countries including India and the disease is endemic in numerous tropical and subtropical areas; these are typically economically developing nations where sanitation and standards of hygiene need improvement. (This is because the main mode of spread of hepatitis A is by the faeco-oral route. It should be emphasized, however, that it can also be transmitted by the parenteral or injection route.)

The faeco-oral route is actually how hepatitis A virus is maintained *in nature* by serial transfer (in the absence of major human or animal reservoirs

Fig. 2 Photomicrograph of a human liver showing massive necrosis (acute yellow atrophy) due to viral hepatitis (x84). There is extensive liver cell (parenchyma) loss. One can see sinusoids, and the reticulin framework which is empty due to the loss of liver cell cords



Let us deal with hepatitis B virus first (designated HBV) since it has been studied more extensively. During acute and chronic hepatitis B infection, several particulate structures, bearing hepatitis B surface antigen (designated HBsAg) are found in the patient's blood (Fig. below). The most numerous of these are the small (22 nm) spherical particles and the long filaments (22 × ~ 200nm), neither of which contain nucleic acid. Also seen is the virion, or the Dane particle — named after its discoverer. This is a 42 nm, double-shelled spheroidal particle which can be separated into a core (28 nm), a 2 nm thick shell and an outer envelope, 7 nm in diameter. Its nucleic acid is a double-stranded circular DNA with a molecular weight of 1·6 × 10^6 daltons. There are several known serological variants, or serotypes of hepatitis B virus. These are defined by different antigenic determinants which can be identified in the outer coat of the virus and the particles. The following are the major determinants: *a*, a group-specific determinant, present in the envelopes of all serotypes; the subtype-specific determinants *d* and *y*, which are mutually exclusive, allelic alternatives, and another such pair, *w* and *r*. All these are coded by the viral genome, and not by that of the host cell. The practical importance of these subtypes is that since only HBsAg produces neutralising antibodies after HBV infection and, since only the *a* determinant is common to the different serotypes of HBV (the sub-determinants being different), a single attack of hepatitis B will confer lasting immunity only against the same serotype, whereas only partial protection will be conferred against the heterologous sub-types. This raises the likelihood of repeated attacks of hepatitis B in a patient. Furthermore, the same individual is susceptible to hepasitis A virus or C virus. Thus, it is well to remember that, in the preparation of a vaccine against HBV, one should include as immunogens at least those subtypes of HBsAg which commonly prevail in that country, or locality. It is well-known, for example, that the most common sub-type occurring in India is *ayw*, but that a small proportion of Indians possesses sub-type *adw*. On the other hand, in northern Europe, the Americas and Australia, sub-type *adw* predominates.



The core antigen, designated HBcAg, is distinct from the surface antigen and this, the DNA, and a DNA polymerase, which is an important virus-coded enzyme, are inside the core. HBcAg is common to all Dane particles and can be seen by electron microscopy, in the nuclei of infected liver cells, whilst HBsAg is seen, together with Dane particles, in the cytoplasm. Probably, the cores are assembled in the nuclei of parenchymatous cells and acquire their outer coat of HBsAg in the cytoplasm. The presence of HBsAg is clearly shown, staining darkly in the cytoplasm of the liver cells, by the Shikata staining technique, as seen in Fig. 3. The DNA polymerase activity regularly appears in high levels in the blood during the incubation period of hepatitis B, just after the appearance of HBsAg. Chronic HBsAg carriers circulate high concentrations of the small, spherical HBsAg particles in their blood for many years. In most carriers, DNA polymerase activity is low in relation to levels seen during the incubation period of acute hepatitis B.

The most detailed studies on the immune response in hepatitis B indicate that anti-HBc (antibody to the core) rises rapidly and persists only as long as HBcAg is being synthesised, being, therefore, a sensitive sentinel of active infection, since it is the first to appear during clinical or subclinical acute infection and persists throughout the HBsAg carrier state. On the other hand, anti-HBs (antibody to surface antigen) rises only 3–24 months later than anti-HBc, and persists almost indefinitely in about 50 per cent HBV infections. They are the only neutralising antibodies and are, therefore, the best heralds of both past infection and immunity.

In 1972, a new antigen, called the *e* determinant, was described by Swedish scientists. Unlike the *a*, *d*, *y*, *w*. and *r* determinants, which all appear to reside on the same particle, the new *e* antigen appears to be on a different particle. The *e* antigen is found exclusively in sera positive for HBsAg. Antibodies to *e* antigen (anti-*e*) occur frequently in HBsAg-positive sera and in some anti-HBs-containing sera. A recent study has shown that neonatal transmission of HBV occurs commonly from asymptomatic, chronic, HBsAg carrier mothers with *e* antigen in their sera, but not from mothers with anti-*e*. Dane particles were detected in the sera of all mothers with *e* antigen, but in none with anti-*e*. This study suggests that the presence of *e* antigen and Dane particles in the sera of chronic carriers is important for infectiousness of mothers for their newborns.

The heat-stability of HBV is remarkable. A preparation of the virus heated at 60°C for 10 hours still contained live HBV. However, heating at 98°C for one minute destroyed it. This important information has been crucial from the point of view of the preparation of an early heat-inactivated vaccine by Drs. Blumberg and Krugman. In addition, it is most important from the public health standpoint, since it tells us that the ideal method of disinfection is autoclaving, or at least boiling for 10 minutes, where HBV-infected apparatus and materials are concerned.

Hepatitis A virus, abbreviated HAV, is a small virus (25–28 nm), possessing cubic symmetry. As with other viruses of this size, empty and full particles exist. In appearance, HAV resembles the RNA-containing picornaviruses and the DNA-containing parvoviruses. Both full and empty particles are antigenically indistinguishable and aggregate when mixed with serum containing antibody to the HAV. Unlike in HBV, a viral envelope has not been found and subunit components have not been identified. In limited studies, HAV is found resistant to heating at 60°C for one hour, and is inactivated by chlorine (1 mg/ml for 30 minutes). Limited biochemical studies on the staining characteristic of the nucleic acid, with acridine orange, suggest that it may be either RNA, or single-stranded DNA. However, the heat-stability of HAV, and other studies, suggest that HAV is similar to the parvoviruses, which are small DNA viruses. Further studies are, therefore, needed to determine to which, if either, of these two classes of small viruses HAV belongs.

A spectacular aspect of the immune response and the peculiar mode of disease-production by HBV is that, antibodies themselves may contribute to the disease state, certain aspects of which may have, what is called, an *autoimmune* basis. During the pre-icteric stage in the patient, large numbers of intact hepatocytes contain HBcAg, HBsAg and HBV, which can be seen by electron microscopy. Liver damage can result from immune cytolysis (cell destruction mediated through antibody and complement) of liver cells, which are infected sublethally with the virus, through the action of complement-fixing antibodies or sensitised T lymphocytes. Furthermore, antigen-antibody complexes between HBsAg and their antibodies may form and be deposited in the kidneys, arterioles and joints and produce well-known manifestations of serious immune complex diseases, such as glomerulonephritis, periarteritis nodosa and arthritis.

In considering the laboratory techniques utilised for the detection of hepatitis A and B, it must be emphasised that until techniques are developed for the isolation of these viruses in cell cultures, we must rely on liver function and serological tests to distinguish viral hepatitis from other causes of jaundice.

Pale-coloured stools tell us that there is improper excretion of bilirubin into the intestines, which occurs in all types of jaundice, except haemolytic jaundice. However, in severe obstructive jaundice (post-hepatic), the stools may be chalky-white, so that, *after further tests*, viral hepatitis can be ruled out. A raised urinary bile pigment level for detection of jaundice is simple to demonstrate, and is usually positive early in the disease.

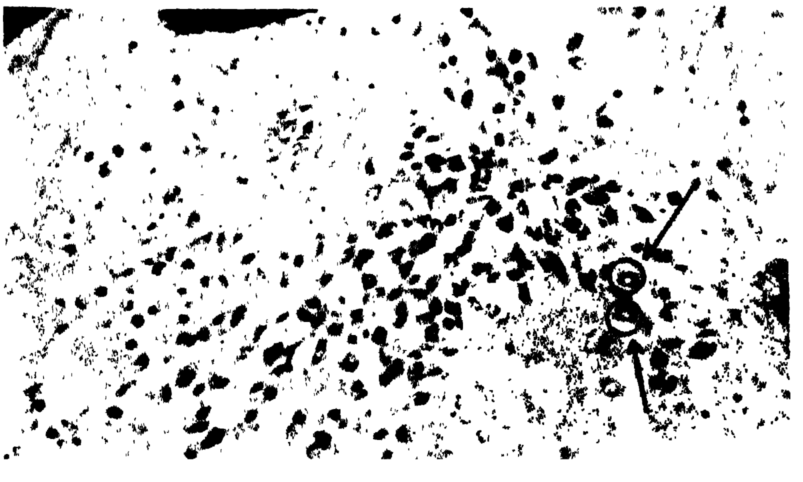
But the tests usually considered essential for detecting viral hepatitis fall into two categories: the non-specific and the specific. The non-specific tests of liver function are the serum glutamic oxaloacetic transaminase (SGOT) and the serum glutamic pyruvic transaminase (SGPT). Liver cells participate in a multitude of metabolic activities and, therefore, contain hosts of enzymes. When damaged, they release these enzymes into the circulation, which are then found in excess of normal levels in the serum. This is particularly true of SGOT and SGPT. Rises in their levels provide a sensitive, early index of liver damage.

The specific tests currently utilised for the detection of hepatitis B by research and diagnostic laboratories and blood banks include (in order of sensitivity) counter-immunoelectrophoresis (CIEP), passive haemagglutination, reversed passive haemagglutination (RPH), and the most sensitive, solid-phase radioimmunoassay (RIA). Immune electron microscopy has mainly research applications.

The most recent development in this field has been the enzyme-linked immunosorbent assay technique (ELISA), for HBsAg detection. This technique has a sensitivity similar to that of RIA.

For the detection of HAV and anti-HAV, the techniques used are immune electron microscopy, RIA and immune adherence haemagglutination assay.

Fig. 3 Photomicrograph of a liver from a case of chronic viral hepatitis B stained with a special technique originated by Prof. Shikata of Japan. Some of the liver cells show pale, unstained nuclei surrounded by the darkly stained cytoplasm containing hepatitis B virus and its products



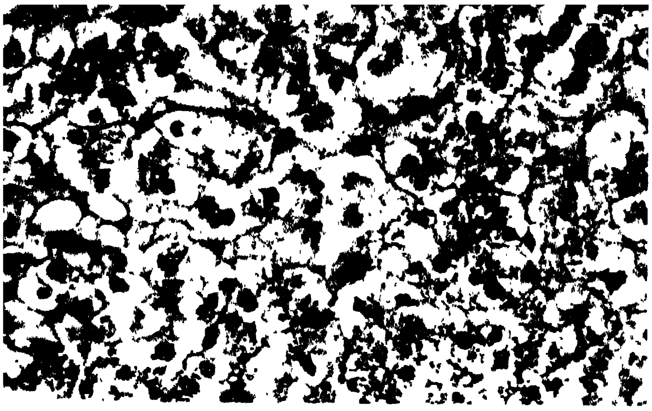


Fig. 4 Photomicrograph of the usual mild form of acute viral hepatitis (x280). The liver cells are enlarged; the cytoplasm is pale and vacuolated (following degeneration)

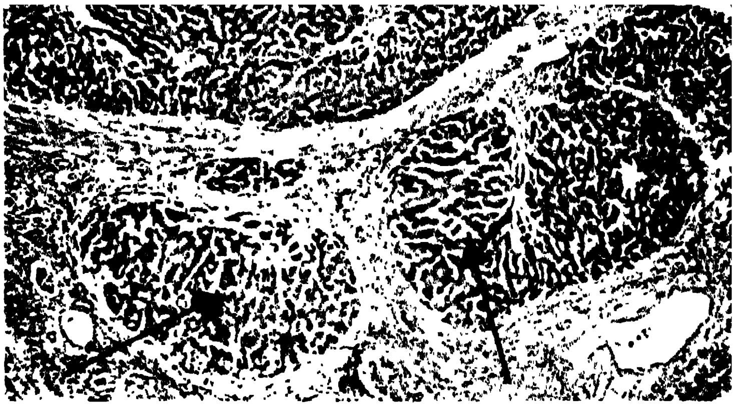


Fig. 5 Photomicrograph of post-hepatitic cirrhosis. Two distinct regenerating nodules (arrows) surrounded by fibrous scarring are evident. Note absence of normal liver architecture (such as central vein and radial arrangement of hepatic cell cords as shown in Fig. 1). The upper portion of the picture shows a very large regenerating nodule

of infection). The serial transfer occurs mainly through close contact in homes, especially where people live under overcrowded and unhygienic conditions. This is also the reason why one can see outbreaks of the disease in institutions for the mentally retarded and during military campaigns! Another reason is that hepatitis A virus is also water-borne, and that may explain its higher prevalence during the monsoon. In New Delhi, during 1955–56, 29,300 hepatitis A cases were recorded when a major water supply system was contaminated by human sewage. In the USA, during 1971–74, 13 outbreaks involving 351 patients were recorded; the cause was the contamination of private or recreational waters with human material.

Numerous food-borne epidemics are well-documented, caused by infected food-handlers' shedding the virus during the incubation period. The source of the outbreak, was possible to detect — usually uncooked food, or food handled after cooking. Another curious mode of spread of hepatitis A is by the ingestion of shellfish grown in polluted waters. Frying of the shellfish destroys the virus whereas steaming does not, because the shells open and the contents may be consumed before the temperature has been raised sufficiently to inactivate the virus.

As regards the age-distribution, in the economically developed countries, hepatitis A occurs at all ages, with about half the number of clinical cases being seen in children below 15 years of age. In tropical and sub-tropical areas, most of the infections are probably acquired in childhood and several of these are subclinical.

The seasonal pattern of hepatitis A is also interesting. In temperate zones, it occurs in epidemic waves, with peaks every 5 to 20 years. In the USA and the Scandinavian countries, it exhibits a marked seasonal variation, peaking in late autumn and early winter. In India, as we have mentioned before, the disease tends to be associated with periods of heavy rainfall. The long-term patterns and trends are not clear, but the figures from several economically developed countries suggest that the incidence of hepatitis A is declining there and that a higher proportion of cases is occurring in adults. Whether this is truly a long-term trend which would be a most heartening sign — or whether it merely reflects the low point of the current epidemic cycle is yet to be established.

The epidemiology of hepatitis B is even more fascinating than that of hepatitis A. Survival of the hepatitis B virus in man is through the persistent carriers (defined as those showing the presence of hepatitis B surface antigen in their blood for more than six months). And the number of such

JAUNDICE IN THE NEWBORN

Neonatal jaundice can appear as a benign, entirely physiological phenomenon in a great majority of newborn babies. This is an entirely normal occurrence and is due to the breakdown of excess of haemoglobin in the normal newborn (19 grams) to about 14 grams, which is considered to be the normal human level. Almost every newborn baby will develop a serum unconjugated bilirubin concentration of greater than 2 mg/100 ml during the first week of life and this transient hyperbilirubinemia has, therefore, been called " physiological jaundice " in the newborn. Such jaundice, which appears within about 24–48 hours following birth, usually disappears between the sixth and the eighth day.

In contrast, some of the other commoner types of neonatal jaundice, which we may call " pathological neonatal jaundice ", include blood group incompatibilities, glucose-6-phosphate dehydrogenase deficiency and numerous other genetically-based varieties which are much rarer. In these types, jaundice is very severe and does not disappear between the sixth and eighth days of life. This is a serious problem confronting the pediatrician because the newborn infant is extraordinary in its limited ability to clear bilirubin from the plasma. In addition, with rare exceptions, the newborn state is the only time when an elevated plasma bilirubin concentration, *as such*, poses a potential threat of brain damage.

The blood-group incompatibilities include, particularly, the Rh and the ABO systems. Here, the jaundice may be severe and can appear very soon after birth. In serious cases, if untreated, it can end up fatally or with a severely damaged brain. The condition is caused by a blood-group called the Rh (for rhesus monkey) factor. If a child is born of an Rh-positive father and is Rh-positive, and if the mother is Rh-negative, there is incompatibility between the two groups. The mother has produced antibodies against the Rh-positive red blood cells of the foetus. (In the first-born, the risk may not be great, but in subsequent pregnancies, the risk progressively increases.) This antibody produces lysis (breakdown) of the newborn's red blood cells with progressively increasing jaundice. This incompatibility can be tackled, provided the condition is detected early and an exchange transfusion, with compatible Rh-negative blood, is given in order to reduce the bilirubin levels in the blood. The situation is very similar in the case of the ABO incompatibility.

In the case of glucose-6-phosphate dehydrogenase deficiency, the red blood cells, which are normally subjected to numerous chemical insults in the body, get damaged at the cell membrane level. The repair of this damage is somehow related to glucose metabolism; the exact mechanism is not fully understood. What is known is that deficiency of the above enzyme leads to improper repair of the damaged cell membrane, leading to lysis of the red blood cells and jaundice. The other rarer forms mentioned are based on inherited metabolic defects of liver cells.

persistent carriers has been estimated at 120 million! The prevalence of hepatitis B surface antigen in ***apparently healthy*** adults varies from 0·1 per cent in parts of Europe, North America and Australia, to 15 per cent in several tropical countries. In India, the figure varies from place to place and a range of five to 50 per cent has been reported. A recently published study conducted at the Haffkine Institute in Bombay utilising the most sensitive detection technique reported a percentage of five in apparently healthy voluntary blood donors.

In low prevalence countries, a major mode of spread is the inoculation of blood and some blood products. The virus is transmissible via blood transfusion, or accidental inoculation of very small volumes of blood as seen in the surgery or in dental clinics. It is also a cause of concern in the case of addicts who take injected drugs. In most cases, the needles are not sterilised; this can also happen in tattooing as well as in piercing of the nose and the earlobes for wearing of jewellery. It has also occurred in situations like mass immunisation, laboratory accidents and acupuncture. Accidental inoculation of the virus in the home, or in dormitories through the communal use of razors, tooth brushes, bath brushes, etc, has also been reported.

In determining the prevalence of hepatitis B virus, an important factor is the transmission from carrier mothers to their newly born infants. The risk of such infection in some countries has been estimated to be as high as 40 per cent. Acute hepatitis B can occur occasionally in pregnancy, when it is often fatal. If it occurs in the second or third trimester, or within two months after delivery, there is a distinct risk that the baby will be infected. This is another subtle method adopted by the hepatitis B virus to ensure its own survival.

Other modes of transmission of hepatitis B may include mouth-to-mouth transmission. Hepatitis B surface antigen has been detected in the saliva of patients with acute hepatitis B as well as in carriers. The disease can also be transmitted sexually. Sexually promiscuous persons have shown a higher than expected incidence of antibody-positive sera. As the hepatitis B surface antigen has been found in the semen, vaginal fluids and menstrual blood, it is possible that it may cross mucosal surfaces exposed to these fluids during intercourse. This might, perhaps, explain the alarming increase of hepatitis B, particularly in the economically developed countries. Interestingly, human transmission studies conducted many years ago — where faecal extracts from hepatitis B patients were given to volunteers orally or by injection — failed to demonstrate the infectivity of faeces and no hepatitis B epidemics due to contaminated food or water have been observed.

Studies in several areas, especially of Asia and Africa, have shown that patients with primary hepatocellular carcinoma show an excess prevalence of HBsAg and anti-HBs, indicators of active HBV infection, as compared with matched controls, or with the general population. This is an interesting finding even though a cause and effect relationship has by no means been established.

Treatment, prevention and control

There are as yet no drugs available in the market that can act specifically against the hepatitis viruses. The usual treatment for viral hepatitis consists of alleviation of the symptoms and the adoption of supportive measures such as administration of vitamins. In *all* cases, consumption of alcohol must be totally prohibited. The patient should preferably be confined to an infectious diseases hospital. The patient must get adequate rest. A high-caloric, low-fat diet is prescribed. Often corticosteroids are administered. However, it must be noted that the role of these drugs in viral hepatitis is, at present, controversial.

Active research is in progress, around the world, directed towards the ultimate goal of finding drugs that can act specifically against the hepatitis viruses. A notable candidate amongst such antiviral agents might be interferon in the case of hepatitis B. Interferon is a natural low molecular-weight protein which is produced by almost all virus-infected cells; when introduced into non-infected cells, it somehow renders them resistant to replication of viruses and thus protects them from the destructive action of such viruses. Interferon derived from cell cultures of human leucocytes was given to patients suffering from chronic hepatitis B virus infection. There was an apparent inhibitory action on some of the hepatitis B virus components, during the treatment. While these preliminary findings are encouraging, as it stands today, interferon is still undergoing trial and is not available in routine clinical practice.

Short of developing specific vaccines (see box, p. 24), the only effective means of control in hepatities A lies in enforcing proper sanitation and hygiene. The virus is particularly resistant to standard methods of water

[illegible] progress

Hepatitis A was previously called infectious hepatitis, and hepatitis B serum hepatitis. These terms were used because it was believed that hepatitis A was transmitted *exclusively* by the faeco-oral route, from person to person, and hepatitis B exclusively by the parenteral (injected) route. Since, however, it was subsequently shown that both viruses could be transmitted by routes other than those exclusively ascribed to them, the non-committal terms, hepatitis A and B, are now used.

While it is true that recorded history is older in the case of hepatitis A, in our opinion, the evolution of virus B need not have been after that of A, since the ancients might well have got infected with virus B, even without possessing syringes and needles. For example, they could have passed the virus from person to person by the mouth-to-mouth or other routes, which today are believed to maintain virus B in nature. The earliest reference to what was probably hepatitis A in western Europe was in a letter written in AD 751 by Pope Zacharias to St. Boniface, Archbishop of Mainz. Subsequently, there were several epidemics, especially during wars, from the Franco-Prussian to the Viet Nam. Between wars, hepatitis A revealed its presence through sporadic cases and minor epidemics. Excellent research on this disease was carried out in England, Germany and the USA between 1908 and 1962, which paved the way towards a breakthrough when Feinstone and others, in 1973, first showed the presence of the virus in the faeces of a patient, using immune electron microscopy.

In hepatitis B research, a masterly piece of epidemiological detective work in 1883 by Dr. Luerman of Bremen revealed the mode of transmission of jaundice, probably caused by hepatitis B virus, although, of course, he did not have the equipment to visualise the virus at the time. There was an outbreak of smallpox amongst the workers at a shipbuilding yard. Vaccination was carried out and the batch of vaccine used contained human immunising material instead of the usual Jennerian calf-lymph vaccine. After a long incubation period, there were cases of jaundice. By excluding water- and food-borne diseases, Dr. Luerman concluded that the outbreak must have been produced by an unknown infectious agent.

Again, further spadework was carried out in Germany, the UK and the USA and a new era in hepatitis B research began, when Dr. Blumberg, in 1964, discovered the Australia antigen, which we today designate as hepatitis B surface antigen (HBs Ag). This discovery was the focal point of several pioneering studies on the fundamental virology of hepatitis B virus, which culminated in the production of a homologous vaccine for use in man. For his original work Blumberg was awarded the Nobel Prize in 1976 (see SCIENCE TODAY, December 1976).

The hope for vaccines

The ultimate answer in the prevention of hepatitis lies in the development of safe, effective and economically available vaccines, specific against each virus, since there is no cross-immunity between the two. Such an ideal can be realised only when both HAV and HBV can be grown in suitable cell culture systems. Nevertheless, there have been some encouraging developments in the hepatitis B vaccine field.

One concerns a subunit vaccine prepared from the small spherical particles of HBsAg To safeguard against any residual, live HBV remaining in the preparations, they were inactivated by formaldehyde. The vaccine was reported to be safe, immunogenic and effective in preventing hepatitis B in chimpanzees, regarded as the only suitable non-human primates which can be infected with HBV. Initial small-scale safety tests of such vaccines are now in progress in volunteers.

The other interesting development concerns another experimental hepatitis B vaccine based on the small spherical particles of HBsAg. These were partially purified on solid immunoadsorbent columns containing anti-HBs of human origin and antibodies of animal origin to human serum. After safety tests in chimpanzees, it was administered to the patients and staff of a haemodialysis unit. The incidences of HBV infection between the immunised group and a group of patients and staff not receiving the vaccine showed a marked difference, even though better controls might have been included in the study

The above-mentioned experimental vaccines are inactivated products and, as such, exhibit the usual advantages (safety) and disadvantages (comparatively short-lived immunity) of " killed " vaccines. In addition, as Dr. Zuckerman has pointed out, the above-mentioned vaccines have one unconventional aspect they utilise viral material obtained from an *in vivo* human source, such as, serum. It is well-known that during the replication of HBV in liver cells, in addition to virus-coded antigens present in HBsAg, proteins from the human host cells are also incorporated into the 22 nm HBsAg particles from which these particular vaccines are prepared. This raises the possibility of the production, when inoculated into the person being immunised, of serious autoimmune diseases, not excluding the chronic forms of hepatitis.

It is interesting to note, in this context, that such vaccines are unconventional, in the sense that, to the best of our knowledge, *they represent the first homologous immunogenic materials from an* in vivo *source, being obtained from man and destined for ultimate use in man.* Hence, scientists ought to be cautious in the long-term evaluation of such products and to explore other avenues of research which might circumvent such problems. Indeed, efforts have been under way in certain laboratories in the USA and the UK to develop a vaccine based on immunogenic small polypeptides obtained from HBsAg, rather than utilising the HBsAg particles themselves. Indeed, the possibility is also being considered of synthesising such small polypeptides *de novo*, so that, hopefully the possibility of production of autoimmune disease can be ruled out. However, one can visualise the limitations imposed on such vaccines from the points of view of production costs and technical logistics.

One approach which, perhaps, has not yet received adequate attention abroad but has been receiving our attention at the Haffkine Institute in the recent past, is the possibility of development of a " live ", attenuated anti-HBV vaccine, in an animal species heterologous to man. Work is going on at the Institute towards development of systems of replication of HBV in common laboratory animals. The advantages of live vaccines are too well-known to merit detailed discussion here; we know the most important advantage is of long-lasting immunity. Their disadvantages, however, such as the possible danger of reversion to the wild types of virus and the possibility of side-reactions, such as allergy resulting from the use of contaminating heterologous antigens, cannot be ignored. What's more, in the case of HBV, one must seriously consider the possible oncogenic potential of this virus, in view of what has been noted earlier about the reported positive correlation between the prevalence of the chronic HBsAg carrier state and occurrence of hepatocellular carcinoma.

In conclusion, we can only state a scientifc truism improvised by us: " The only good vaccine is a dead vaccine — until a safe and effective live one can be developed ! "

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sterilisation, including chlorination at the usual levels of concentration. Hence, boiling for 10 minutes is the safeguard for potable water. However, ultimate control lies in achieving optimal levels of general community hygiene and safe disposal of faeces. Besides the faeces, the blood and, possibly, the urine of patients must be considered infectious and adequate measures must be taken for their disposal. In the laboratory, every precaution must be taken to ensure that the staff do not get infected. The method of choice of sterilisation of equipment is autoclaving (steam pressure); glassware can be sterilised with dry heat (at 180°C for one hour).

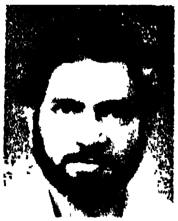
The efficacy of giving pooled, normal human immunoglobulin in the attenuation or prevention of clinical hepatitis A has been established. However, it should be within the limits of availability of supplies and be directed mainly towards high-risk individuals.

In the case of hepatitis B, infection can be minimised by avoiding the use of blood and certain blood products, unless absolutely necessary, and making certain that all syringes and needles and surgical and dental instruments are properly sterilised. Autoclaving is the method of choice. Also, routine screening of all blood donors at blood banks for hepatitis B surface antigen, at least by a low-sensitivity method such as CIEP (but, preferably, more sensitive methods such as RPH and RIA) should be made obligatory.

Although human hepatitis B immunoglobulin has already come on the market abroad, due to its high cost and limited availability, it would be neither realistic nor justifiable to utilise this preparation with every transfusion. It should be reserved only for high-risk cases and patients who are likely to receive multiple transfusions or who undergo major cardiovascular surgery, or repeated haemodialysis, and also surgeons and research workers who may have accidentally infected themselves.

In conclusion, it may confidently be stated that viral hepatitis A and B are infections, ubiquitous in their distribution, in which nothing could be more true than the old adage that an ounce of prevention is better than a pound of cure.

Dr. M. V. N. Shirodkar (49), Head of the Department of Virology at the Haffkine Institute, Bombay, studied at the Johns Hopkins University, Baltimore, USA, and later at the Yale University School of Medicine. In 1963, he received his ScD from Johns Hopkins University for his work on the tumour-producing Rous sarcoma virus. Besides his current research work on hepatitis and Rous sarcoma, Dr. Shirodkar teaches microbiology and applied biology at the Bombay University.



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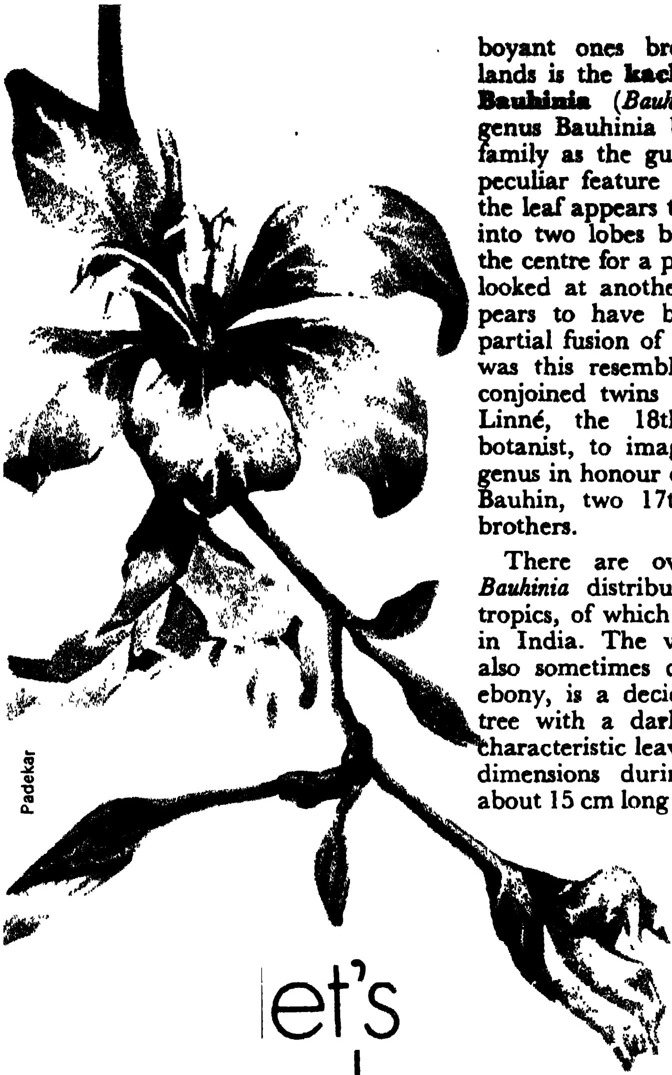


Padekar

Variegated Bauhinia

let's get to know our trees!

5

SOME MORE VILLAGE TREES

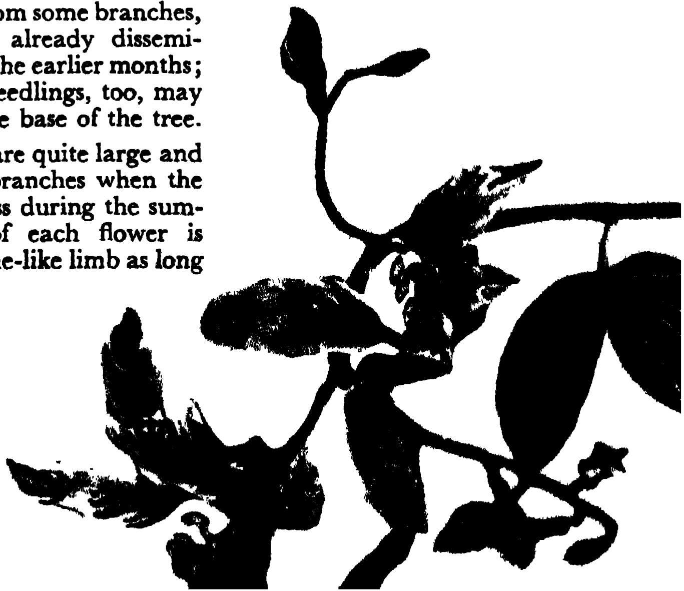
While the relentless monsoon winds lash the Indian landmass from the south-west, and rain-bearing clouds hasten to discharge their burden to sprout new life in every glade in the countryside, the memory of the brilliant floral displays of spring and summer fade out to make way for the verdant splendour of trees in dark emerald attire. This is the time for vigorous growth and multiplication of the species. Some trees like the *kachnar* and *ber* have cast their seeds around to be nurtured and strike root in the damp soil; others like the *kadamba* and *babool* are on the verge of bursting into bloom.

An indigenous tree which can hold its own in beauty amidst the flamboyant ones brought from foreign lands is the **kachnar** or **variegated Bauhinia** (*Bauhinia variegata*). The genus Bauhinia belongs to the same family as the gul mohr but has one peculiar feature which sets it apart: the leaf appears to have been divided into two lobes by a slit going down the centre for a part of the length, or, looked at another way, the leaf appears to have been formed by the partial fusion of two oblong lobes. It was this resemblance of the leaf to conjoined twins that prompted Carl Linné, the 18th century Swedish botanist, to imaginatively name the genus in honour of Jean and Gaspard Bauhin, two 17th century herbalist brothers.

There are over 250 species of *Bauhinia* distributed throughout the tropics, of which about 40 are found in India. The variegated Bauhinia, also sometimes called the mountain ebony, is a deciduous medium-sized tree with a dark brown bark. The characteristic leaves attain fairly large dimensions during the monsoon — about 15 cm long and almost as broad. During this time a few ripe pods (15 to 30 cm long and containing 10 to 15 small, flat, roundish seeds) may still be found hanging from some branches, though most have already disseminated their seeds in the earlier months; newly germinated seedlings, too, may be found around the base of the tree.

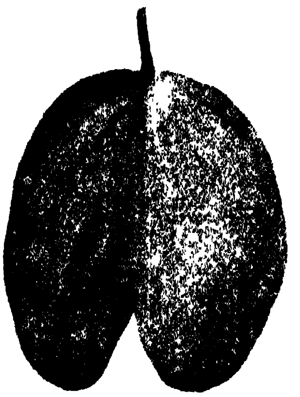
Kachnar flowers are quite large and bloom on the bare branches when the tree is almost leafless during the summer. The calyx of each flower is tubular with a spathe-like limb as long as the calyx from which it has arisen. Five distinct petals spread out and curve slightly into broad claws. Two varieties of kachnar are recognised on the basis of petal coloration: one with purple flowers of which four petals are a light purple and the fifth large and coloured deep purple, and the other with white flowers in which the fifth petal is variegated with yellowish-green or dark purple. The flowers, disposed on short racemes, or in the angles of the leaf stalk, are fragrant and attract bees which thus act as pollinators; often sunbirds may be seen to probe the flowers for nectar.

The kachnar is found wild in many parts of India — from the western Himalayan foothills eastwards up to Assam and in western and central India; yet, in many parts of the country, the tree is largely grown as an ornamental tree. Its bark yields a tannin and also a gum; a rough fibre obtained from the bark provides a coarse cordage. In indigenous medicine, bark extracts are used in skin diseases and ulcers. Its seed extract is said to possess the property of agglutinating the blood cells. Bauhinia leaves make a rich and nutritious fodder for livestock. Villagers in the Ghat areas of Maharashtra make forays into the forest during the rainy season in search of edible pot herbs, and the fresh buds and leaves of *Bauhinia* species, called *kavlya-chi-bhaji*, are made into soups and curries. A Gond song describes how one may plant ten kachnar trees and care for them and yet they would not grow as well as those in the forest! The white-flowered kachnar is associated with Lakshmi, the goddess of wealth. Kalidasa's *kanchan* is believed to refer to *Bauhinia acuminata*, a small tree (or shrub) with large, pure white flowers which bloom all the year round. In Maharashtra, the leaves of *Bauhinia racemosa* are exchanged on the



Purple Bauhinia
(*Bauhinia purpuria*)

Padekar



Bauhinia leaf

Dassera day as tokens of gold and goodwill.

Interestingly, not all *Bauhinias* are trees; an exceptionally interesting species is the **chambelli** (*Bauhinia vahlii*) — a gigantic woody climber which may grow beyond 40 metres in length, and up to half a metre in diametre. This rather unusual plant is sometimes encountered in mixed deciduous forests, but while the casual visitor may be impressed by its very large leaves, creamy white flowers or the 30-cm-long fur-covered pods, the forest personnel look upon it as a destroyer of many fine timber-yielding trees.

The big pods of this climber burst with a loud report during the summer and hurl their large, flat seeds some distance away; the pod then becomes spirally twisted and dries up (see photograph on p. 29). Chambelli leaves serve as plates and are also used for making rustic umbrellas; its seeds are eaten roasted (the seeds are believed to possess both tonic and aphrodisiac properties!).

The **kadamba** or **neepa,** both Sanskrit names for *Anthacephalus kadamba*, has had a long association with Indian life and culture. Of the three Indo-Malayan species of the genus *Anthacephalus*, the *kadamba* is indigenous to our country. It is a medium-sized deciduous tree which can reach to a height of about 10 metres or so, the trunk growing straight up and supporting a dense, round crown of fine foliage. In India the tree is widely distributed — from the sub-Himalayan tracts extending eastwards to Assam and southwards down the Western Ghats to Karnataka and Kerala (and even Sri Lanka). In its natural habitat, it grows well in moist conditions on well-drained alluvial soil. The kadamba's rapid rate of growth during the first six to eight years, attaining almost maximum size in about 20 years, and its close foliage, make it a good shady and ornamental roadside tree.

The leaves of the kadamba are oblong-elliptic, between 12 and 24 cm long, fairly broad and end in a short, blunt point; the upper surface of the dark green leaves has a sheen and one can discern a fine woolly covering on the lower surface. The orange-coloured flowers which appear in large numbers from May to September are small and tubular and are arranged on a fleshy, globular head giving the cluster the semblance of a fluffy, hairy ball about 5 cm in diametre; these flower-heads are solitary, highly fragrant and hang from peduncles (stalks). The globular fruits are actually composed of individual pyrenes (capsules) aggregated together in each fleshy head (such fruits are known as syncarpiums).

The fragrant flowers of the kadamba attract a variety of small insects and bees; the fruits are edible, both for humans and cattle (and bats, too). In fact, the natural regeneration of this tree depends rather upon cattle excreta which contain many undigested small seeds. The fluffy flower-heads are often collected by village children for play.

Kadamba wood is soft and easy to work with, moderately strong and is used for making cheap boards, packing cases, tea chests, etc; in some regions, dugout canoes are hewn out of trunks of the tree. The wood pulp is used for paper-making.

Since ancient times, kadamba flowers have been used for offerings in temples around which the trees were often planted. Buddhist monks, too, have been known to grow these trees. In ancient lores, it is reverentially associated with Lord Krishna and his beloved Radha who used to meet him as he played his flute under the tree. It is even believed that Krishna climbed a kadamba tree to dive into the river Jamuna in order to subdue the serpent Kaliya. In his monumental work *Meghadootam*, Kalidasa wrote how women decorated their hairdo's with kadamba blossoms during the rainy season. Also a " woman and tree " design in sculpture (found near Mathura) belonging to the Kushan period depicts a woman with a sword in one hand and touching the ball-like flowers of the kadamba with the other. The release last month by our Post and Telegraph Department of a stamp depicting the *kadamba* in bloom (below, left) is indeed a fitting tribute to a tree of such great antiquity and significance.

The **baheda** is a tall and handsome tree of our countryside with its spreading canopy, light grey-brown bark and leaves clustered at the ends of the branches. The botanical generic name, *Terminalia*, is derived from this characteristic terminal clustering of the leaves; the specific name, *bellerica*, is the Latinised form of its Arabic name. Of the 16 *Terminalia* species India has, the most important ones commonly encountered are (besides baheda): the **harda** (*T. chebula*), the **desi badam** (*T. catappa*), the **asan** or **ain** (*T. tomentosa*), and the **arjuna** (*T. arjuna*). All are indigenous trees; some have even been mentioned by Valmiki in the *Ramayana*.

The baheda, known in Sanskrit as *vibhitaka*, is a deciduous tree largely distributed throughout peninsular India, but rarely seen at altitudes above 1,200 metres, and is not found in the arid zones. The tree reaches a height of about 40 metres with a girth of two to three metres. The lower portion of the straight trunk is often buttressed to give it strength and rigidity. Its leaves, which are shed during the summer, appear shortly before the monsoon and are a dull brick-red in colour at first and mature into thick, dark green; broadly elliptical, the leaves are about the size of an outstretched hand.

Between March and June (and sometimes later), the tree comes into bloom; these are small, creamy-white flowers, cup-like in appearance with ten stamens poking out from them. The numerous scented flowers are borne on thin stems and a number of these spikes are borne in the axils of the terminal clusters of leaves. (Actually, it is rather difficult to spot the small flower clusters from the ground level as these grow high up in the canopy.)

The roundish fruits, on the other hand, are conspicuous because of their brown colour and large numbers. Each fruit is about two to three cm in diameter and is covered with a coat of fine, brown, velvety fur. When the tough pulp is removed along with the fruit skin, a hard stone enclosing the seed is seen. Many herbivorous animals eat the outer portion of the fruit, and on many occasions one may find the hard stones nibbled away with the seed inside missing — this is the handiwork of squirrels. Sometimes piles of these stones, systematically smashed open, can be found under the tree, a sure sign that village folk have been collecting the edible seeds. The seeds have a nutty flavour, but eaten in large numbers, they produce a narcotic effect. Some villagers eat the seed kernel with betel leaf and betel nut as a treatment for indigestion. The seeds yield an oil which has been used as a hair oil, and for soap-making; it also has a purgative action like that of castor oil. The oil is also employed as an external application for rheumatic pains.

Baheda leaves are eaten by livestock and are also fed to the tussar silk-worm (*Antheraea mylitta*). Though baheda wood is hard and strong, it tends to crack during working and it does not take a polish; however, being durable under water, it is used in the construction of boats and planking. By far the most important part of the tree is its crop of fruits, known commercially as Belleric myrobalan, which contain about 20 per cent tannin and are, therefore, used for tanning leather and ink-making.

A still more economically important myrobalan tree is the chebulic myrobalan (*T. chebula*). A medium-sized deciduous tree, this myrobalan, known as **harda** (*haritaki* in Sanskrit), is found in the deciduous forests practically all over India. Its leaves have a rounded base unlike the tapering bahedas. The flowering is similar to the belleric myrobalan's and the fruits ripen from November to March. The fruits are ellipsoid rather than globular and are ribbed from end to end longitudinally. These are collected from January to April, dried, classified and sorted according to quality and sold commercially, especially for tanning and medicinal use. The tannin content of the fruit exceeds 30 per cent (the tannin is of the pyrogallol type with a high ellagitannin content; this makes it very useful for tanning of sole leather). The tannins of harda are in great demand and large quantities are exported. For instance, harda tannins have been used in ink-making, for internal treatment of locomotive feed waters, as an additive in oil drilling compositions, as an anti-corrosion agent, in petroleum purification, etc.

Harda fruits have for long been used as a laxative and tonic; it is one of the three components of the Ayurvedic preparation, *triphala churna*, the other two being the amla (*Emblica officinalis*) and baheda (*T. bellerica*). The laxative effect is attributable to a glycoside in the fruit pulp resembling Sennoside-A, the active principle of senna pods (*Cassia angustifolia*). An anti-spasmodic substance, called chebulin, has also been extracted. The fruit pulp is used by herbalists for application to bleeding gums and as a dentifrice. Harda wood is hard and is used for making posts, beams, tool handles, etc.

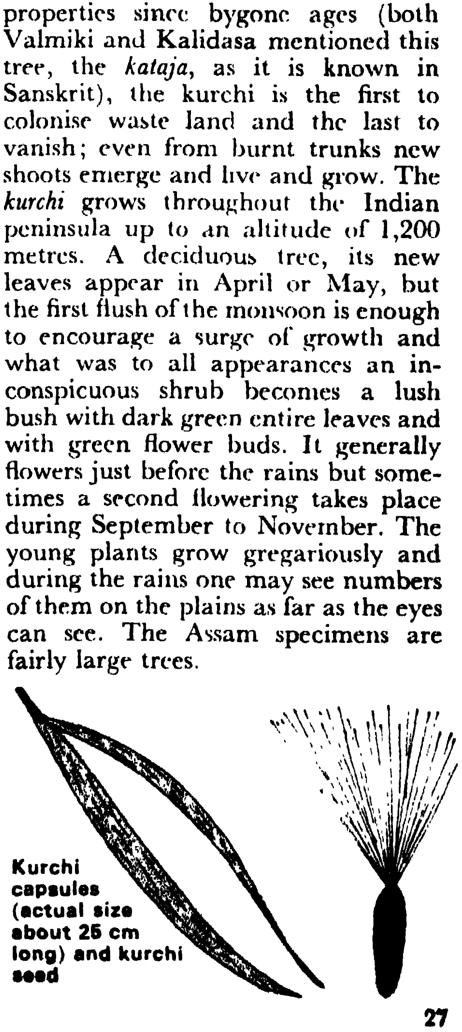
The winged fruit of ain

In the rainy season, the **desi badam** (*T. catappa*) goes into dense foliage and grows heavy with fruits which are ellipsoid and green, with a tinge of red. This deciduous tree is a native of the Andamans; it is now extensively grown in our gardens and estates as an ornamental tree. Its visual appeal lies in the symmetrical whorled disposition of its branches, and the large green leaves that turn dark red as they age and fall off.

The kernels of desi badam are edible and have an almond-like flavour. The leaves make a good fodder for livestock and feed for the tussar silk moth larvae. The hard shells covering the seeds have been shown by Indian chemists to be rich in pentosans and are, therefore, a good source of the chemical furfural. The bark contains a colouring matter that is used for dyeing silk and other natural fibres into various shades of grey, fawn and brown. In South India, herbalists are said to use the juice of young leaves as an application for scabies and skin conditions. The wood, too, is useful as a good constructional timber.

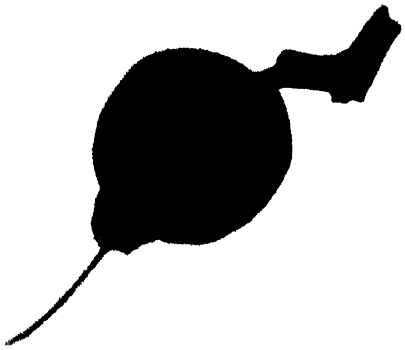
All the three *Terminalia* species we have described here have fleshy fruits, but this is not a common feature of the genus. Two species of *Terminalia* whose fruits are altogether different — they have five wings (these are thin, dry, expanded portions of the external covering) — are the **ain** and the **arjuna** trees. Both are Indian trees known since ancient times: Valmiki had referred to the former as *sarja* and to the latter as *arjuna*. These two trees are essentially forest trees. The arjuna is evergreen, has a white bark and usually grows along a river bank or a stream, whereas the ain is a deciduous tree, with dark blackish-brown, highly fissured bark growing amidst other trees on flat ground generally. Flowering and fruiting occur during summer, and when the rains come, their winged fruits are knocked down and tossed around by wind and rain; the fine symmetry of the fruits is lost as the wet wings are frayed by the elements, but the scattered fruits stand a good chance of germinating and taking root, more so because animals do not seem to find the fibrous winged fruits very attractive as food. Both trees yield excellent hard timber. Arjuna bark has been used in indigenous medicine and some investigators have reported diuretic and blood pressure relieving properties and a general tonic effect in cirrhosis of the liver.

Largescale felling of trees in forest areas leaves massive scars in the terrain that may require many years to be recolonised by new tree and shrub species. In such areas, and even in patches destroyed by forest fires, one small tree usually survives — this is the **kurchi** (*Holarrhena antidysenterica*). Famed for its medicinal properties since bygone ages (both Valmiki and Kalidasa mentioned this tree, the *kataja*, as it is known in Sanskrit), the kurchi is the first to colonise waste land and the last to vanish; even from burnt trunks new shoots emerge and live and grow. The *kurchi* grows throughout the Indian peninsula up to an altitude of 1,200 metres. A deciduous tree, its new leaves appear in April or May, but the first flush of the monsoon is enough to encourage a surge of growth and what was to all appearances an inconspicuous shrub becomes a lush bush with dark green entire leaves and with green flower buds. It generally flowers just before the rains but sometimes a second flowering takes place during September to November. The young plants grow gregariously and during the rains one may see numbers of them on the plains as far as the eyes can see. The Assam specimens are fairly large trees.



Kurchi capsules (actual size about 25 cm long) and kurchi seed

The leaves are 10 to 30 cm long and about 5 to 15 cm broad and ovate or elliptical. The flowers are bunched together and look like small white bouquets. The thin white petals spread out and separate from a tubular corolla. The fruits are a pair of long, slender, tapering capsules containing numerous small seeds with a tuft of silky hair at one pole; these hair help carry the seeds over long distances on the wind when the capsules burst (in the following summer).



Kumbha flowers (left) and below it the kumbha fruit (photo by S. R. Nayak)

The kurchi belongs to the dogbane family (*Apocynaceae*) and is, therefore, potentially poisonous, but it has some medicinal value as well. The aerial parts of the tree contain alkaloids, the principal one being conessine (0·2 to 4 per cent); the maximum concentration occurs soon after the rainy season. This alkaloid is an effective agent in treating amoebiasis, but it produces some nervous symptoms like tremors and restlessness, giddiness and also intestinal disturbances. The kurchi is officially recognised by the Indian Pharmacopoeia which lists two of its preparations: liquid extract of kurchi, and kurchi bismuth iodide. The preparations are made from the bark (commercially known as conessi bark) and contain 2 per cent of the total alkaloids.

The flowers are eaten cooked and the leaves are used as livestock fodder.

Padekar

Kurchi flowers and leaves

The finer specimens from Assam yield a soft, light-coloured wood used for carving, making boxes, toys, combs, etc and also light furniture.

A fairly large tree which does not look very conspicuous in a mixed forest is the **kumbha** (*Careya arborea*). This deciduous tree becomes noticeable only in March or April when a rather unpleasant sweetish smell pervades the summer air; if one looks around, one can spot the kumbha bereft of leaves, sporting a few clusters here and there of those malodorous creamy flowers. The large flowers look like brushes with their numerous stamens displayed prominently; each flower has four petals and four sepals of the thick calyx. Come the rains, and new leaves grow to attain a large size. These leaves are like those of the Indian almond. In July and August, the tree bears fruits, about 10 cm in diameter, which are pitcher-shaped (hence the Hindi name *kumbha*).

There are nine species of *Careya* in the Indo-Malayan region. The kumbha is found in most of India's forests up to 1,600 metres altitude. Kumbha fruits have a sweet, fibrous, edible pulp in which are embedded the peanut-sized seeds which are poisonous, presumably because of their high content of saponin, a highly irritant substance. Yet the tree has medicinal value; the bark is a demulcent in coughs and colds, and also an antipyretic agent (reduces fever). The fleshy calyces contain plenty of mucilage and is used to treat coughs and cold; it is dried and sold under the name of ' vakumbha '. The tannin-containing leaves are used as wrappings of *bidis* and cheroots. The inner bark rubbed on footwear is said to keep away leeches.

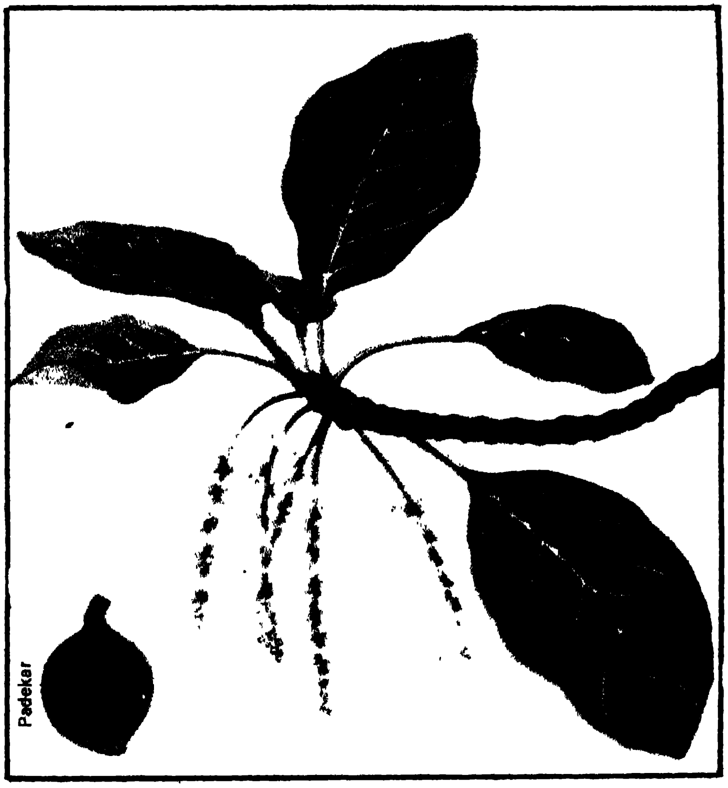
Kumbha wood is heavy and durable, especially under water; it is difficult to saw but gives smooth shining finish and takes a good polish. It is used for agricultural implements, cabinets, gun-stocks, sleepers, etc after treatment. The bark is fibrous and gives a coarse cordage; it is also used to make brown paper.

Most of us at some time or other must have tasted the plum-like fruit of the **Indian jujube** or **ber.** The ber tree has a long history in India and the earliest records can be traced to the Chalcolithic Age (1500 to 1000 BC). The ber fruit has been mentioned in our ancient texts like the *Yajurveda*, the *Brahmanas*, medical texts and the works of Kautilya, Panini and Patanjali.

In recent years, the confusion that existed regarding the exact botanical identity of Indian jujubes appears to have been resolved. The consensus is that the true Indian jujube (ber) is *Ziziphus mauritiana* and that the introduced Chinese jujube is *Ziziphus jujuba* under which name every kind of ber used to be lumped together.

Our ancients had their own method of identifying ber types and three of them were recognised: (i) *badara* with large-sized fruits (*badari* of Valmiki); (ii) *kuvala* with average-sized fruits; and (iii) *karkandhu* with small, orange-red or brown fruits. Botanists believe that the first two refer to varieties of *Z. mauritiana* and the third to the *Z. nummularia* (*chanibor* of Maharashtra).

(Right) Climbing Bauhinia (chambelli) showing a burst pod with a spiral twist (photo by S. R. Amladi)



(Left) Myrobalan

The ber tree itself is moderately sized and in the wild state reaches up to a height of 12 metres. The leaves are single and three-nerved with either one or two prickles at the base of each leaf-stalk. There is some variation in the leaf sizes and especially fruit sizes because of the existence of polyploidy (multiple chromosomes) in the cultivated varieties. The wild type is not popular because of the small amount of pulp as compared to that of the cultivars. To encourage vigorous growth and good fruit crops, budding or grafting to root stocks is done.

The wild ber thrives well in the drier regions and may be found up to an elevation of 1,600 metres. It prefers an open terrain for its growth (a light demander) and the seeds disseminated by various natural means germinate very well — to such an extent that it may even be looked upon as a pest.

The flowering season of ber varies somewhat with the region in which it grows, but generally the season is November to January or April to October, and the fleshy fruits with a hard stone in the centre are obtained from October to March. The flowers grow in profusion from axillary cymes. Each small, greenish-yellow flower resembles a five-pointed star because of the disposition of the triangular petals.

Some horticultural varieties of the ber are known, for example, *uniran, sanaur; kaithili* and *dandan;* the differences between these are recognised in the amount of the pulp, the size and shape of the fruits and the stones, etc. The fruit, which can be eaten as such when ripe, is sometimes made into candies. The Burmese prepare a delicious syrup, with small-sized sour-and-sweet ber boiled with molasses or jaggery; this is called " *zee-yo* ". Ber fruits are rich in sugars, vitamin C and minerals.

Medicinally, the ber fruit is regarded as cooling and tonic; it is one of the ingredients of the indigenous medicine, *Joshanda*, used for chest complaints. The kernels are said to be sedative and soporific, and are also made into poultices for wounds. *Badara* is believed to be an oral contraceptive.

Ber timber is excellent wood for hard and durable items like axe handles, gunstocks, yokes, turnery and wheel parts. Ber leaves provide good fodder; the ber tree is a good host of the lac insect.

The ber has a special religious significance for the Sikhs — the " sorrow-removing tree " at the Golden Temple in Amritsar is a ber tree.

In this and the previous issue, we have talked about some of the important trees that one may come across in the countryside, around villages and on the forest fringes. Yet, we have hardly covered even a fraction of the rich variety that can still be seen. True, the richness of our ancient *vanas* (forest groves) and sylvan glades are now just a memory in lores, yet the sight of countless plants asserting themselves in their green garb is in itself a reassuring experience.

S. R. AMLADI

Ber

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ROUND-UP OF RESEARCH

NEUROPHYSIOLOGY

Role of Endorphins

The discovery of the chemical 'enkephalin' capable of imitating the actions of natural opiates, such as morphine, in the brain has given a new dimension to studies on the physiology of pain and mood (see Science Today, March 1976, p. 26). What is noteworthy is that, subsequent to this, a large number of pain-killing chemicals, all peptides related to enkephalin but differing widely in pharmacological properties, were discovered. Known as the 'endorphin' family, these are now under detailed study. A significant discovery about endorphins, both from theoretical and from the practical points of view, has now been made by J. A. H. Lord, A. A. Waterfield, J. Hughes and H. W. Ksoterlitz of the Unit for Research on Addictive Drugs, University of Aberdeen, Marischal College, Aberdeen, UK. They have shown that not only are there several opioid peptides in the brain with different characteristics, but they act through several different types of receptor on the surface of the cells they activate. The details are reported in *Nature* (**267,** 495, 9 June 1977).

They conducted two sets of experiments. In the first, they tested the ability of peptides to depress the electrically-induced contraction of two kinds of voluntary muscle — guinea pig ileum and mouse vas deferens. In the second, they tested their ability to inhibit binding of tritium-labelled naloxone and leu-enkephalin in the homogenates of guinea pig brain.

If the receptors were the same for all the tissues and all the different peptides, then the endorphin that is the most potent in one test would also be the most potent in the others. In fact, from the differences in potency of the peptides they observed in different tests, they concluded that there may be about four different types of receptors.

They state that the present evidence is not sufficient to allocate different receptors to different physiological functions. However, their results do indicate that the system of opioid peptides, similar to the catecholamine system, is of considerable complexity in that several peptides are matched by multiple receptors. The results also suggest chemical differences between the members of the endorphin family. The large ones (α and β endorphins) are found in the intermediate and anterior lobes of the pituitary gland in high concentrations and they are not easily destroyed by enzyme action. The smaller ones (met- and leu-enkephalin) are present in lower concentrations in widely spread areas of the central and autonomic nervous systems and are destroyed very rapidly indeed by enzymes. It is possible that the big "parent" endorphins may be hormones with relatively long-term effects; for instance, they may be involved in dimming pain perception in special situations such as the battlefield and childbirth. The little ones may play the role of fast-acting neuromodulators or neurotransmitters in the moment-to-moment exchange of information between brain cells.

ASTROPHYSICS

Black Hole in Milky Way

What lies at the centre of our Galaxy — a pulsar, a quasar or a black hole? It is not possible for us to see the centre since clouds of gas and dust lie in between. However, from infra-red and radio observations we know that dense compact objects do exist in the centres of other galaxies. Strong evidence that the heart of our Galaxy may contain a massive black hole has now been provided by a team of radio astronomers from the US National Radio Astronomy Observatory (NRAO) in a recent issue of the *Astrophysical Journal Letters* (**214,** 61, 1 June 1977).

Prof. K. I. Kellermann and his colleagues D. B. Schaffer, B. G. Clark and B. J. Geldzahler had used long-base line interferometry, a standard and well-established technique for locating small radio sources to observe the compact radio source Sagittarius A West at the centre of the Milky Way at a wavelength of 4 cm. By hooking up the existing radio telescopes from the west to the east coast of the United States (Tyngsboro in Massachusetts, Green Bank in West Virginia and Goldstone in California) they achieved a baseline of 105 million wavelengths for a radio interferometer.

Their results, combined with those from shorter baselines, indicate that the radio emissions from the centre are concentrated in a region of size in the range 0·01 to 0·02 arc seconds, confirming the observations made two years ago (see Science Today, March 1976, p. 25). The new evidence is that they have discovered a region less than one-thousandth of a second across, emitting 25 per cent of the central power. Translated into linear measure, this represents a size 10 times the Earth-Sun distance.

The radioluminosity of the centre of the Galaxy was found well below that of the quasars. But the volume emissivity was much greater as compared to quasars. The observed brightness temperature of five million degrees ruled out a thermal origin for the radiation. The emission is probably generated by relativistic particles and magnetic fields. The radio size, in fact, corresponds to a black hole of 100 million solar masses; this is close to the upper limit for a condensed object at the centre of our Galaxy. The authors say: "The detection of a radio source with milli-arc second dimensions has been suggested as a possible test of the presence of a black hole." The observations do not prove that such a black hole exists, but neither do they go against the suggestion.

BOTANY

Flavonoids in Fossil Leaves

The chemical evolution of flowering plants has been studied by Karl J. Niklas and David E. Giannasi of the New York Botanical Garden, Bronx, New York, USA, from an analysis of the organic chemistry of a dozen still-green fossil leaves of the tree *Zelkova oregoniana*, a member of the elm family. The trees were buried under volcanic ash at Succor Creek in Oregon some 30 million years ago.

The New York biochemists particularly studied the plant pigments, flavonoids. The most complex flavonoids are found only in the evolutionarily advanced flowering plants, while the lower ferns and mosses have only simple types and algae have no flavonoids at all. These chemicals perform numerous functions in plants such as attracting bright coloured insects, regulating growth, capturing light and protecting the plant with bitter tastes.

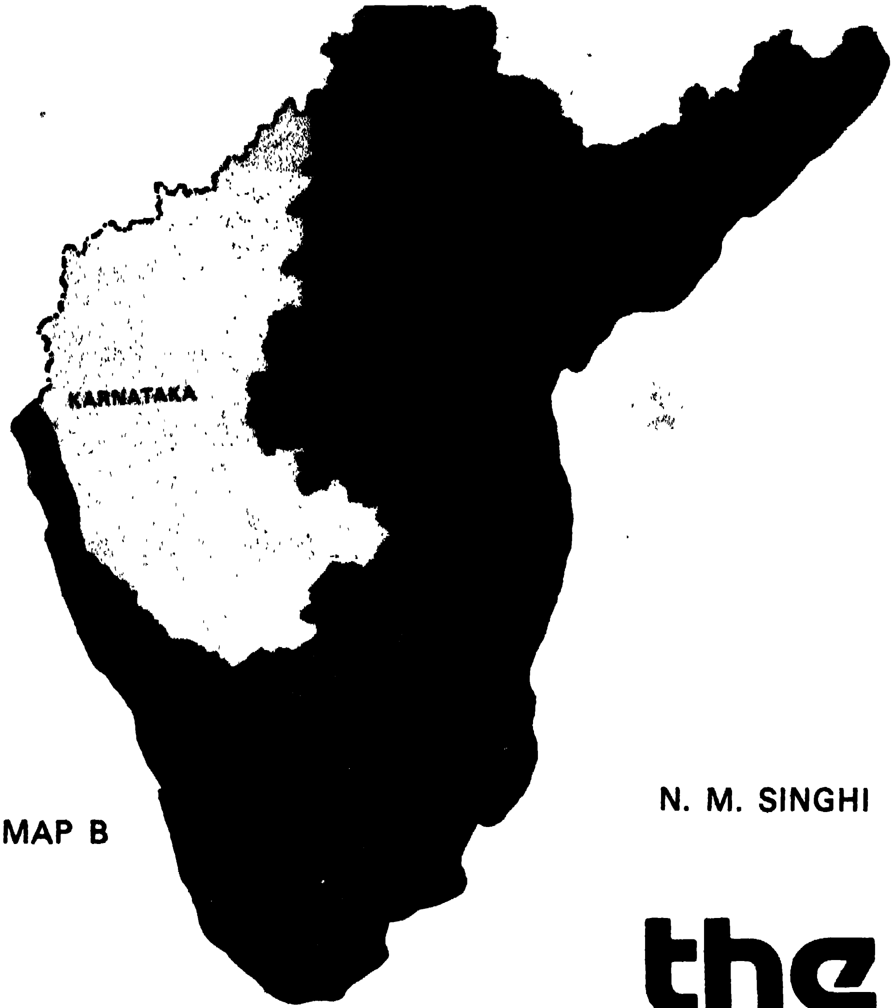
(Contd on p. 55)

the four colour conjecture

a post-mortem

N. M. SINGHI

The simplest way to show that four colours are necessary for flat maps is to draw four regions so that each one touches the other three, as in the map A drawn here. Each of the three outside regions requires its own colour, and the centre must have still another. In map B, three colours are sufficient for the four states Karnataka, Tamil Nadu, Kerala and Andhra Pradesh, but one more colour is needed to distinguish the outside seas. The fact that there are flat maps which require four colours was demonstrated about 123 years ago. Since then mathematicians had been attempting to draw a flat map which needs five or more colours. Recently Apple and Hakin have shown that this cannot be done



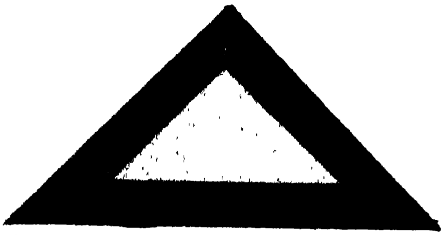
MAP B

An eventful date for decades to come in mathematics would be 22 July 1976. For, the well-known four colour problem, which fascinated mathematicians, engineers, physicists and linguists alike — even laymen did not hesitate to try to produce a solution to it — was announced as solved on this date. A battle fought by many fertile and devoted minds for the past hundred years has thus, perhaps, come to an end. Professors Wolfgang Hakin and Kenneth Apple of the University of Illinois, USA, have finally proved that it is possible to colour any flat map by four colours, so that no two adjoining regions are coloured alike (Fig. 1). To understand the significance of their solution, it is necessary to go back to the 19th century.

The four colour problem, which came to be known in mathematical circles as the "four colour conjecture", was first posed about 123 years ago. Francis Guthrie, a postgraduate student at the University College, London, observed that four colours were enough to colour the counties on a map of England in a way that no contiguous counties were of the same colour. He wondered whether that was true for all maps! A letter dated 23 October 1852 from Professor Augustus de Morgan to Sir W. R. Hamilton also mentions the problem. De Morgan acknowledges in the letter that the problem was first asked by one of his students, who was, perhaps, Guthrie.

Fig. 1

MAP A



The problem, however, did not create any stir in the mathematical world for another 30 years. It appeared in print, for the first time, in June 1878, in the form of a question posed by the well-known mathematician Cayley. Cayley again stated the problem in the first volume of the *Proceedings of the Royal Geographical Society* in 1879.

The first attempt to solve the problem was made by Kempe. He used an argument which may be considered as a modification of the one used to prove the "two colour theorem" (Fig. 2). He claimed that he had proved the four colour conjecture. Kempe's paper was published in 1879-1880.

About ten years later, after Kempe's death, P. J. Heawood published a paper in which he showed that there was a flaw in Kempe's proof. Heawood, however, pointed out that the proof could be modified to show that *five* colours were enough to colour any flat map in a way that no two regions with common boundaries had the same colour. Kempe, in fact, left this world without realising that a problem which he had the satisfaction of "solving", was to continue to defy one and all in the years to come. (P. G. Tait is another famous mathematician who had given an unsatisfactory "solution" to the problem in 1880.)

Mathematicians as a lot are very fond of generalising, particularly when they are unable to comprehend something. It gives them a deep satisfaction to pose a problem or prove a theorem in as much generality as possible. Heawood, hence, did not leave the matter where he picked it up. He first observed that given any flat map one could draw a new figure by joining the capitals of the adjoining regions. This new figure is called a *dual map* of the original (Fig. 3 is an example of a dual map). Graph theorists do not use the word "capitals". They call the points denoting capitals, 'vertices'. The advantage of a dual map is that you have only to colour the vertices in place of whole regions in the original map.

This is clear because vertices in the dual map are joined, if and only if, in the original map the corresponding regions have a common boundary. To distinguish this new type of colouring, we shall call it vertex-colouring. Thus, vertex-colouring of a map means you colour the vertices in such a way that any two vertices which are joined get different colours. The vertex-colouring is easier to visualise and graph theorists prefer to state their theorems in terms of the new type of colouring rather than the usual map colouring.

A further interesting observation is that, drawing a map on a plain piece of paper or a sphere is one and the same thing. The similarity is evident from what is known as stereographic projection (Fig. 5, p. 36). Thus, the four colour conjecture can now be rephrased: "Every map drawn on a sphere is vertex-colourable in four colours."

Heawood now asked the question, why should we consider maps drawn on a sphere only? Why not maps drawn on, for example, a tea cup or a tenecoit ring? How many colours will have to be used for vertex-colouring of maps drawn on these different surfaces? Mathematicians, again, do not have too many different types of surfaces (Fig. 4, p. 34) in their terminology. They do not distinguish between an elephant, a guava or a sphere. All these are surfaces of *genus zero* to them. A tea cup with one handle or a tenecoit ring has a surface of *genus one*, while a sugar-bowl with two handles is a surface of *genus two*. Roughly speaking, mathematicians think of every three-dimensional object as if it were a tea cup with a number of handles attached to it. The number of handles is called the *genus* of the surface of the object. To

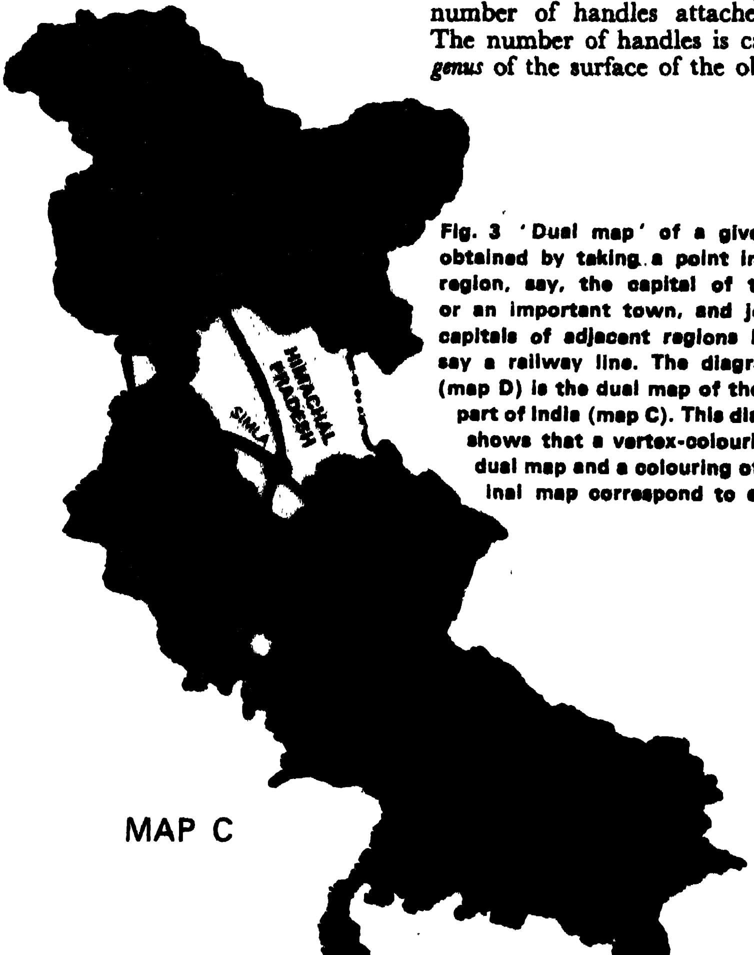


Fig. 3 'Dual map' of a given map is obtained by taking a point inside each region, say, the capital of the region or an important town, and joining the capitals of adjacent regions by curves, say a railway line. The diagram below (map D) is the dual map of the northern part of India (map C). This diagram also shows that a vertex-colouring of the dual map and a colouring of the original map correspond to each other

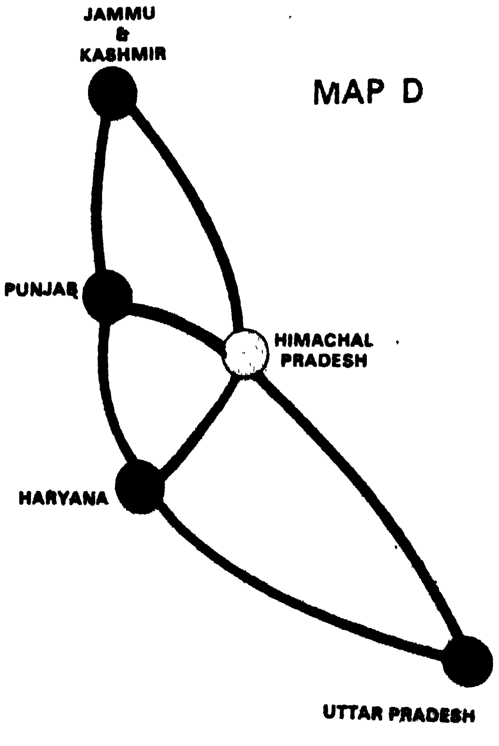
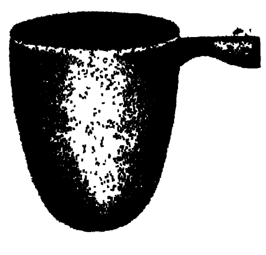


Fig. 2 The 'two colour theorem' states that, if a flat map could be drawn entirely of straight lines which begin and end at an edge, it could be coloured in two colours without having any adjacent areas of the same colour. The three figures below demonstrate the theory. The first flat map is in two colours. When a line is added (second map), two colours still suffice. This is shown in the third map. The colours below the line remain the same, while all colours above the line have to be *reversed*.



GENUS 0

GENUS 1

GENUS 2

GENUS 3

mathematicians, a sphere is the same as a tea cup without a handle and hence its genus is zero.

Heawood, in fact, posed a general problem. What is the smallest number C(S) of colours required, so that any map on a surface could be coloured in C(S) or less colours? He conjectured a general formula for C(S), namely,

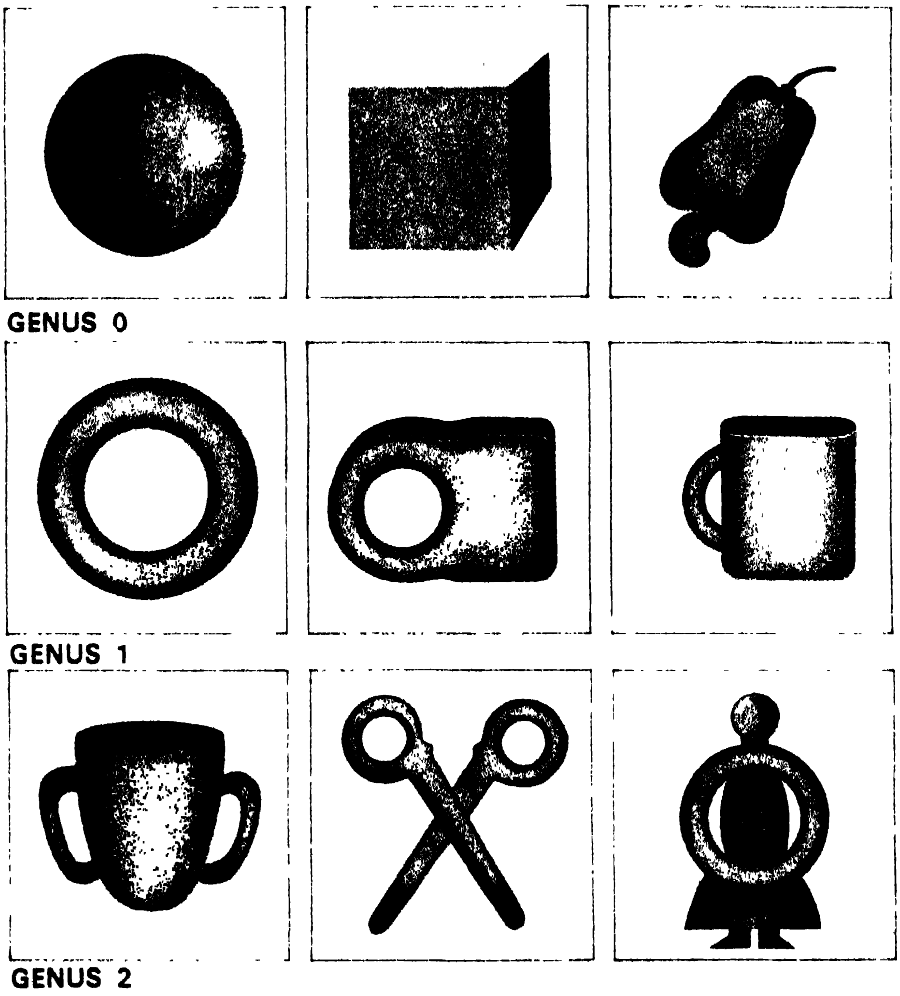
$$C(S) = \left[\frac{7 + \sqrt{1 + 48\, g(S)}}{2}\right],$$

where g(S) is the genus of the surface S and the brackets denote that we have to take only the whole number in the right hand side of the equation and forget the fractional part (for example, [4·56] = 4). If g(S) = 0 (a sphere), the above equation precisely gives C(S) = 4, that is, the four colour conjecture. Thus, the four colour conjecture became a part of a much more general problem. The problem of proving the above equation for all surfaces S, later became one of the central problems in graph theory. Graph theorists called it Heawood's conjecture.

Heawood thought that he had solved the problem for all surfaces of genus more than zero. Unfortunately, he too had made some serious errors in his arguments, and thus the problem again remained wide open. Many mathematicians tried to prove Heawood's conjecture, in general, or the four colour conjecture, in particular, and in doing so made significant contributions to the development of graph theory. Finally, in 1968, J. W. T. Youngs and G. Ringel were able to show that Heawood's conjecture was true for all surfaces of genus *more than zero*. Alas, their methods did not work for surfaces of genus zero. Thus, the four colour conjecture continued to remain a mystery.

A person who made significant contributions to the four colour problem and related topics was H. Whitney who published his research papers on the subject around 1935-40. His approach was quite different in that he tried to link the problem with other mathematical theories and fields. His work is responsible for initiating a new theory, known as the theory of matroids. A promising feature of this theory is that it presents a unifying approach to the newly developing fields of graph theory, combinatories, finite geometries, etc — known in mathematical circles as finite mathematics.

Fig. 4



The objects in the same row in the above diagram can be obtained from each other by what mathematicians call "continuous" transformations. These are changes in the shape of a surface, which leave certain basic properties unaltered, and the surface, as a whole, unbroken. For a mathematician, the figure thus transformed has not changed at all. Roughly speaking, objects which can be turned into each other by means of twisting, bending, or other shaping, in other words without making or removing a hole, fall into the same class.

Thus, for example, a sphere cannot be turned into a ring by these transformations, but it can be deformed into a cube, or into a guava. Indeed a child performs such operations when he picks up a ball of modelling clay, squeezes it into the shape of a box or into a disc without tearing it.

The present solvers of the four colour problem, Apple and Hakin, strangely enough did not have to use the complicated techniques developed earlier. Their method is essentially a modification of Kempe's method. They have about 400 pages of detailed, si logical arguments, and about 1, hours of computer time on some of the best computers in the world, to arrive at their solution.

They have proved the four colour conjecture by what is called an "existence proof" — an argument which shows that something exists without necessarily producing it for inspection. To understand their proof, let us first see what Kempe had done way back in 1879-1880, and where he went wrong.

Kempe tried to prove the conjecture by showing that no flat map which required five colours exists. This would have proved the four colour conjecture. *If* there are such flat maps (requiring five colours), there must be a flat map requiring five colours and having a minimum number of regions. Such a flat map is called a minimal *five-chromatic* map. By definition, if such a map exists, any map having a smaller number of regions will require only four, or less, colours.

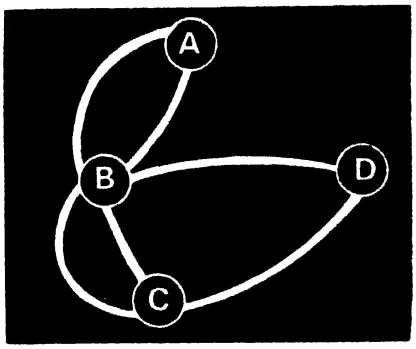
Kempe easily showed that no region in such a minimal five-chromatic map could have just two or three adjoining regions. For three, the argument went as follows : suppose a region *a* in such a map G has precisely three adjoining regions *b*, *c* and *d* (Fig. 7a, p. 37). Let us now construct a new map H, by amalgamating regions *a* and *c* in map G (Fig. 7b). The map H has clearly fewer regions. Since G was the *smallest* five-colour map, the new map H can be coloured in four colours. But in such a colouring of the total map H, only *three* colours need be used to colour the three regions *b*, *d* and amalgamated *a* and *c* (Fig. 7c). A colouring of map G in four colours is achieved by preserving the colours of all the remaining regions of H and colouring the triangular region *a*, with the colour not used in *b*, *c* or *d* (Fig. 7d). Thus, the minimal five-chromatic map G can be coloured in four colours — a contradiction ! Hence no region in a minimal five-chromatic map can be "triangular" like *a*, that is, with just three adjoining regions.

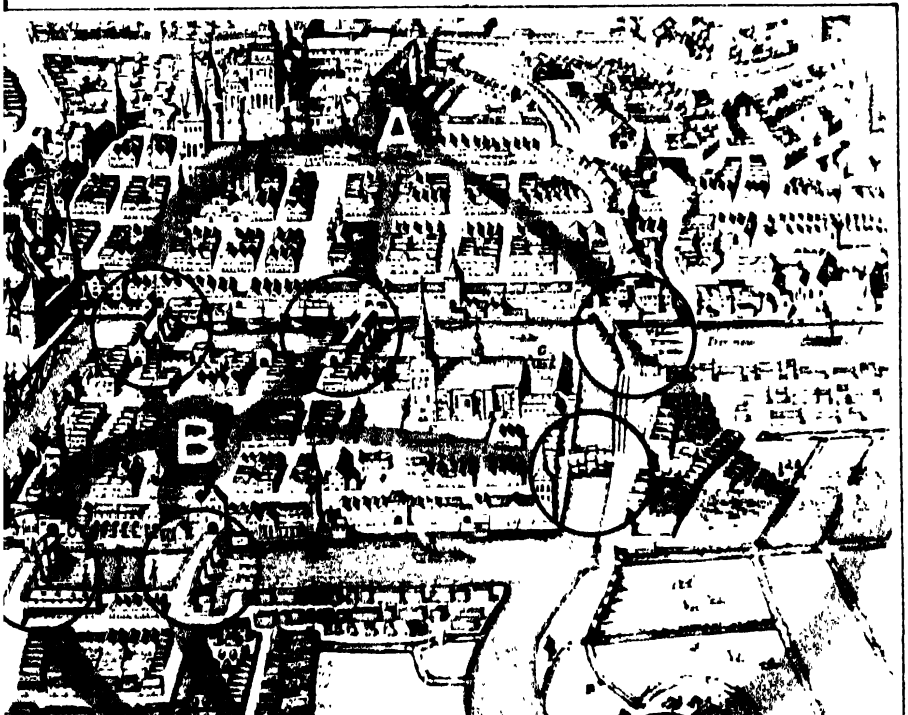
Kempe invented a more complicated argument (which we shall not discuss here) to show that no region

GRAPH THEORY AND THE KÖNIGSBERG PUZZLE

The present century, and in particular the last two decades, have witnessed the steady development of a new field of mathematics known as graph theory. Graph theorists essentially study the properties of figures which consist of points, some of which are joined by simple curves.

There are many factors underlying this new interest in the study of graphs. Perhaps, the most important have been the demands from the new fields of applications: game-theory and programming, communication theory, electrical networks and switching circuits as well as problems from biology and psychology. A number of popular puzzles can also be formulated directly in terms of graphs. Thus came the realisation that many such questions contain a mathematical nucleus of general importance.





The origins of graph theory can be traced a couple of centuries back to a solution of a problem dealing with ancient bridges. It had been a traditional belief amongst the people of the Prussian city of Konigsberg that it was impossible to cross all its seven bridges without *recrossing* one's route at some point. The Swiss mathematician, Leonhard Euler, demonstrated mathematically the validity of this popular belief. The old map (left) shows Konigsberg and the river loop that devides it into four regions (marked A, B, C and D). Connecting these regions are seven bridges (in black circles). The heavy grey lines indicate all the possible routes between the regions using bridges. The diagram of the city (above) in which lettered points and lines correspond to those marked on the map shows why it is impossible to cross all the bridges without recrossing at least one of them.

In such a graph, some retracing is unavoidable whenever there are three or more points at which an odd number of paths converge -- this was shown by Euler. It was a tribute to Euler's genius that he solved a problem in graph theory over 150 years before the subject came into its own as a distinct area of mathematical investigation.

N.M.S.

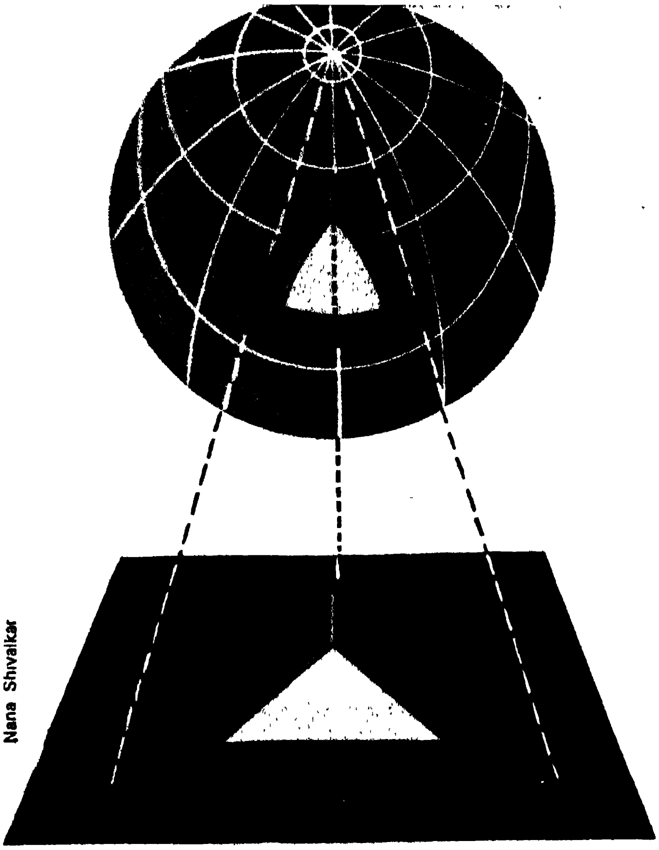


Fig. 5 Stereographic projection on a plane, of a map drawn on a sphere, is obtained thus: take a point on the sphere. Call it north pole. Now join each point of the map on the sphere with the north pole and extend each of these straight lines to get a corresponding point on the plane. These points together give the projected flat map.

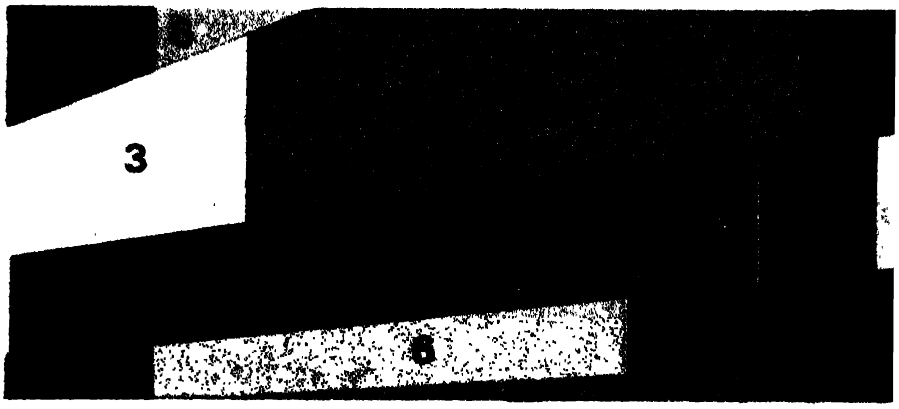
An interesting observation is that, the same map on a sphere can be drawn in many different ways on the plane by changing the location of the 'north pole'. Many a time, stereographic projection is used to draw maps of various parts of the earth in a geography book

in a minimal five-chromatic map could have precisely four adjoining regions. He thought he had also proved that no minimal five-chromatic map could contain a pentagon (a region with precisely five adjoining regions). If he would have done this, he would have solved the four colour problem, for it can easily be proved, and Kempe had done it, that *every flat map contains a region which has five or less adjoining regions.* However, there was a flaw in Kempe's argument for pentagons, as pointed out by Heawood.

Let us try to see, crudely though, what Kempe was doing. He proved that the set of figures consisting of regions with precisely two, three, four or five adjoining regions was *unavoidable*, in the sense that *every flat map contains at least one member of the set.* He tried to show that each of these figures was 'reducible', that is, if it occurred in a flat map which required five or more colours, then that map could not be a minimal map, and a smaller flat map existed which would require five colours. Thus, he attempted to show that there exists "an unavoidable set of reducible figures". But while he could prove the 'unavoidability' of his set of triangular, rectangular and pentagonal regions, there was a flaw, as we have said before, in his 'proof' of the reducibility of the pentagon.

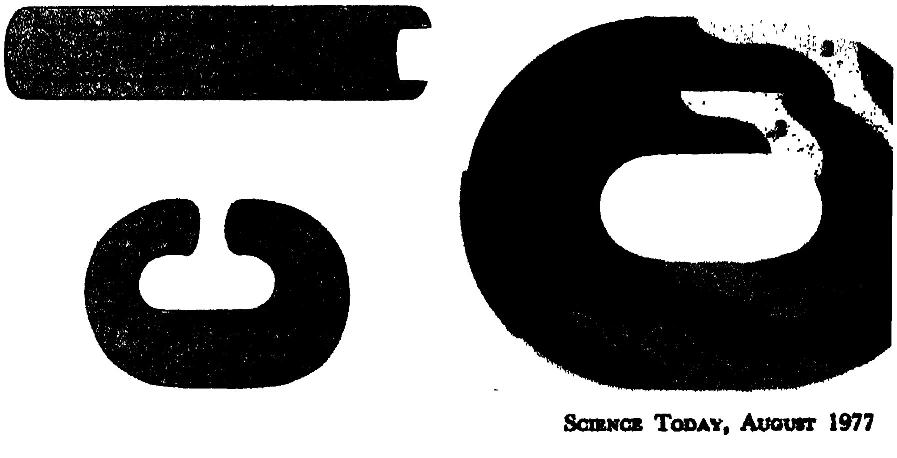
The idea of reducible figures has been developed further from 1912 onwards. G. D. Birkhonff, P. Franklin, C. E. Winn, A. Bernhart, H. Heesch, Jean Mayer and W. Tutte are among the many who significantly contributed towards this development. Even though a great deal of progress was made, no one had any reasonable intuition of a set of figures which was unavoidable and which contained only reducible figures. However, Apple and Hakin have succeeded in producing such an unavoidable set of reducible figures.

They have proved the four colour conjecture in two main steps. In the



MAP F

Fig. 6 Heawood's number $C(S) = \left[\frac{7+\sqrt{1+48}}{2}\right] = 7$ for a ring. In the diagram, a map (map F) with seven colours is drawn on a rectangular strip ABCD. If the opposite sides AD, BC and then AB, CD of the strip are pasted together (below, left), a surface with genus one, that is, a ring, is obtained (below, right). The map so obtained requires precisely seven colours. Heawood had shown that this is the best possible



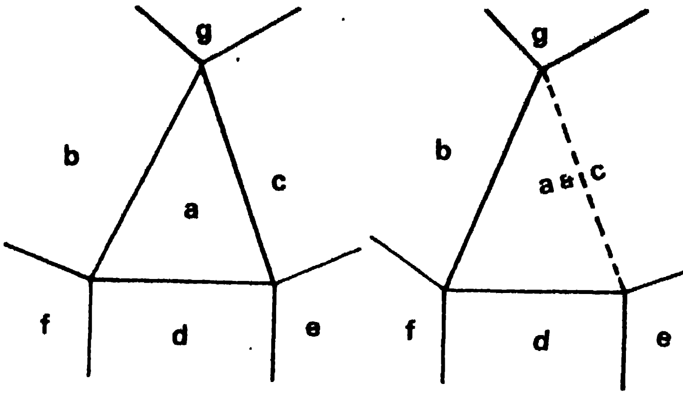
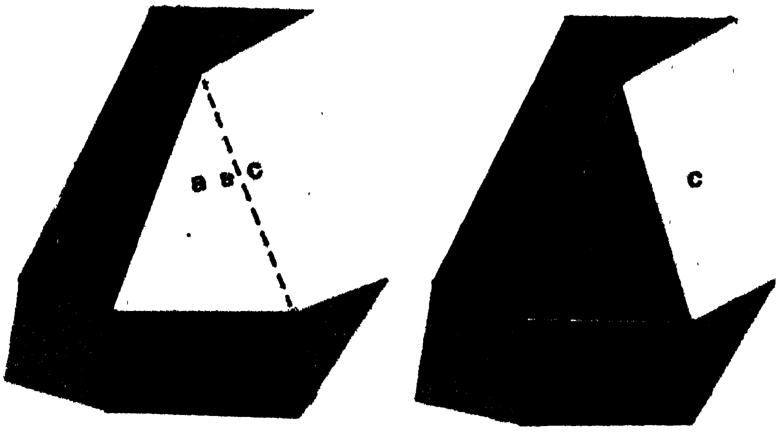


Fig. 7 (a) MAP G (b) MAP H

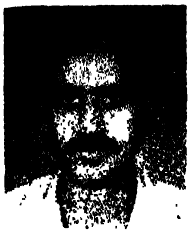


(c) MAP H (d) MAP G

first, they constructed a set of about 2,000 reducible flat maps, that is, figures which cannot occur in a minimal five-chromatic map. It is this part which requires detailed calculations and long hours of computer time. In the second step they have shown that, if any map does not have as a part any of the above 2,000 figures, then the surface on which it is drawn must have genus more than zero. In other words, every flat map has at least one of these 2,000 figures as a part. Thus, the set of these 2,000 figures is unavoidable. The unavoidability of the set is shown by a process first developed by Heesch — known as the principle of discharging (by analogy with the idea of moving charges in the electric network). These two steps together show that there is no *minimal* five chromatic map and hence that there is *no* flat map which requires five or more colours.

Four hundred pages is indeed quite long for a research paper in mathematics — perhaps, the longest so far. An interesting section of Apple and Hakin's paper is devoted to show that if one uses their methods, the length of the paper cannot be reduced very much. However, there might be some other method to prove the same conjecture. Mathematicians are still at it.

What are the reactions of graph theorists to their spectacular announcement? In a cafe, while amongst graph theorists, the author heard the following comment: " It is disheartening to see that the problem has been solved by simple arguments. It was thought that at least this problem of graph theory will require more sophisticated tools." Another comment was: " Who will verify these 400 pages of argument and 1,200 hours of computer time ?"



Navin M. Singhi (28) is a fellow at the School of Mathematics, Tata Institute of Fundamental Research, Bombay. After his PhD from Bombay University in 1974, he joined the Department of Mathematics, Colorado State University, USA, as a post-doctoral fellow (1974–75). During 1975–76 he was a visiting assistant professor at the Ohio State University, Columbus, Ohio, and later visiting professor at the University of Waterloo, Canada. His special field of interest is combinatorial mathematics. *Recommends reading:* 1. Harary, Frank 1961 *Graph Theory*. Addison-Wesley Publishing Company. 2. Chin, W. G. & Steenrod, N. E. 1966 *First Concepts in Topology*. L. W. Singer Co. 3. Ore, O. 1967 *The Four Colour Problem*. Academic Press.

IN LIGHTER MOMENTS

Despite the iconoclasm of Islam, the main factor behind Islamic astronomy was astrology. And the astrology was also the final cause of astronomy's death. The Islamic or Arab school of astronomy which was born in Baghdad Academy in the ninth century AD, reached its peak at the Samarkand observatory set up by Ulugh Begh, grandson of Tamerlane or Timur. Here fresh tables of planetary movements were prepared and a new catalogue of more than 1,000 stars was drawn up. It was here that, with the help of these tables and catalogues, Ulugh Begh cast his eldest son Abdul Latif's horoscope, which foretold that he would kill his own father. To be on the safe side, the ruler-astrologer disowned and exiled Abdul Latif and made his younger son heir to the throne. However, with the help of some neighbouring chiefs and emirs, Abdul Latif raised an army, attacked and destroyed Samarkand and got his father killed.

* * *

Edward Jenner, the father of vaccination, was a thorough disciple of John Hunter. Once at a dinner party, people were discussing which part of a candle flame was the hottest. Jenner, then quite young, recalled his teacher's injunction — " Why think? Why not try the experiment? " And without a word, he put his finger at the burning flame's base and found that he could retain it in that position for a short while. But when he repeated this just above the tip of the flame, he could not hold his finger there even for a second. And so he confidently announced " There, gentlemen, the question is settled."

* * *

Much before Robert Koch discovered the bacillus of tuberculosis (in 1882), Jean Antoine Villemin, also of France, had a hunch in 1867 about the existence of such a germ. His theory "resembled Pasteur's picture of germs floating about in the air". Villemin's personal rival and malicious opponent, one Dr. Pidoux, ridiculing this theory, ironically said, " If TB is due to a microbe, then all we doctors have to do is to set our nets to catch the germs of TB and find a vaccine ! " However, poor Pidoux could not imagine that his comment belied its intended sarcasm and would prove to be truly prophetic.

* * *

When the Nazis came to power in Germany, one of their several missions was to end communism. They subjected many German scientists to persecution. The American geneticist, Hermann Joseph Muller, issued a strong protest declaring that to scientists the Nazi doctrine of racism was as reprehensible as the " deadly regimentation of ideas that any dictatorship imposed . . . Good or bad genes are not the monopoly of particular people or of persons with features of a given kind."

S. N. MUNSHI

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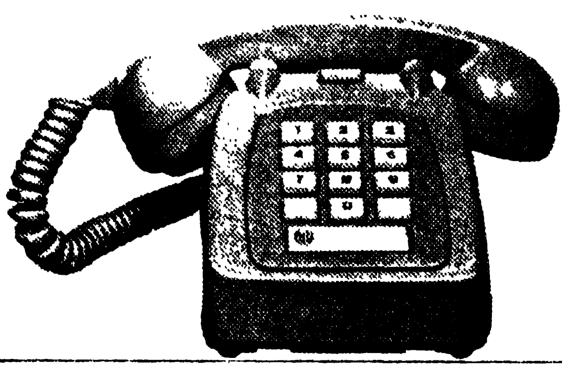

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IDEAS & INVENTIONS

Solar-powered crop sprayer

A solar energy-powered light crop sprayer has been developed by a team of scientists and engineers at the International Institute of Tropical Agriculture (IITA) at Ibadan in Nigeria. The work was part of a package of low-applied-energy farming systems aimed at raising farm productivity without using heavy machinery.

A simple solar energy collector, about 0·093 sq metre (a square foot), can provide the power needed for either herbicide or insecticide spraying. The solar energy falling on a square metre of sunlit surface is about 1,000 watts (1 kW). The collector is equipped with 38 wafer-thin silicon photo-voltaic cells which provide more than five watts of power in average sunlight — much more than what is needed to operate the spinning disc of the sprayer.

The surplus power charges a battery of eight nickel-cadmium cells in the handle of the sprayer to provide power even through patches of cloudy dull weather. At the IITA, in continuous operation for eight hours a day and seven days a week, the batteries were found as full of charge as on the first day. Besides storing the excess energy, the Ni-Cad cells also function as a voltage stabiliser, maintaining a constant 7,000 rpm.

The solar panel rests lightly on the operator's shoulders like a very light 'sunshade' — the panel and the shoulder-supports weigh only 1·2 kg. The batteries get charged as soon as the wiring from the panel is plugged into the sprayer in the open field. The motor spinning the sprayer disc operates when switched on for spraying. Admittedly, the device is somewhat of a gimmick at its present stage of development, but the small size of the solar generator emphasises the very low applied energy involved.

RAY WIJEWARDENE

[Mr. Wijewardene is an agricultural engineer at the International Institute of Tropical Agriculture, Ibadan, Nigeria.]

A super sweetener

A sugar derivative which is 500 to 600 times sweeter than sugar has recently been reported. The new derivative which is obtained by chlorination of sucrose using thionyl chloride does not have any after-taste associated with amino acid-derived sweeteners such as saccharin and cyclamate. The compound, 1′, 4, 6, 6′ tetra chloro-1′, 4, 6, 6′-tetra deoxygalacto sucrose, was discovered during a study of stereospecific chemical reactions of sucrose derivatives. The compound has the four most reactive hydroxyl groups of sucrose replaced by chlorides.

None of the extensive health and safety tests required to market a food additive has been done on the compound yet. The tests are very necessary, as a number of organic compounds are known to be carcinogens and many more have become suspect in recent years. In the end, even if the compound does not turn out to have commercial value, its development will be important in understanding what makes compounds taste sweet. An enhancement of sweetness by selective substitution by chlorine has not been observed before in sucrose or any carbohydrate.

V. C. MALSHE

Coal solubilisation by grafting

Though coal is the most abundant of the fossil fuels, there are certain problems in utilising it. The high sulphur and ash content make it inefficient and cause sulphur dioxide and particulate pollution. To reduce the sulphur and to get rid of the ash, attempts are being made to liquefy coal. Hydrogenation of coal under high pressure and also its conversion to methanol have been extensively studied but still remain uneconomic propositions.

The latest approach is to solubilise coal by grafting monomeric compounds on anthracite or bituminous types of coals. Though the technique is frequently used for solubilising "difficult-to-dissolve" polymers, it can now be applied to coal (*Chemical & Engineering News*, **55**, 26, 1977).

In this process, graft initiators and monomers are slurried with powdered coal. The grafting takes about six hours. To liquefy the product, solvents derived from coal or petroleum can be added. The resultant liquid resembles fuel or crude oil and can be transported and stored in much the same way.

The choice of the monomer is important to the solubility of the treated coal. Non-polar substituents such as methyl, ethyl and propyl groups enhance the solubility in aliphatic hydrocarbons while phenyl, methyl phenyl and similar aromatics make coal soluble in aromatic solvents.

Since the process takes place at atmospheric pressure and mild temperature conditions, capital investment in plant and equipment will be much lower than that needed for techniques like hydrogenation. The important parameters which will decide the cost are the monomer used, the amount of monomer required, and the extent of conversion of the coal to the soluble form. These are being studied further. The sulphur in the coal is not solubilised to a large extent.

The solubilised coal so obtained can be used as a liquid fuel of low ash content. Mixed with kerosene, it can be a substitute for diesel. It may also be used as a chemical feedstock. India has very large coal deposits, and the process should be very suitable if an integrated facility is set up at the coal mines.

V. C. M.

WHAT ARE WE ADDING TO OUR FOODS?

K. K. G. MENON

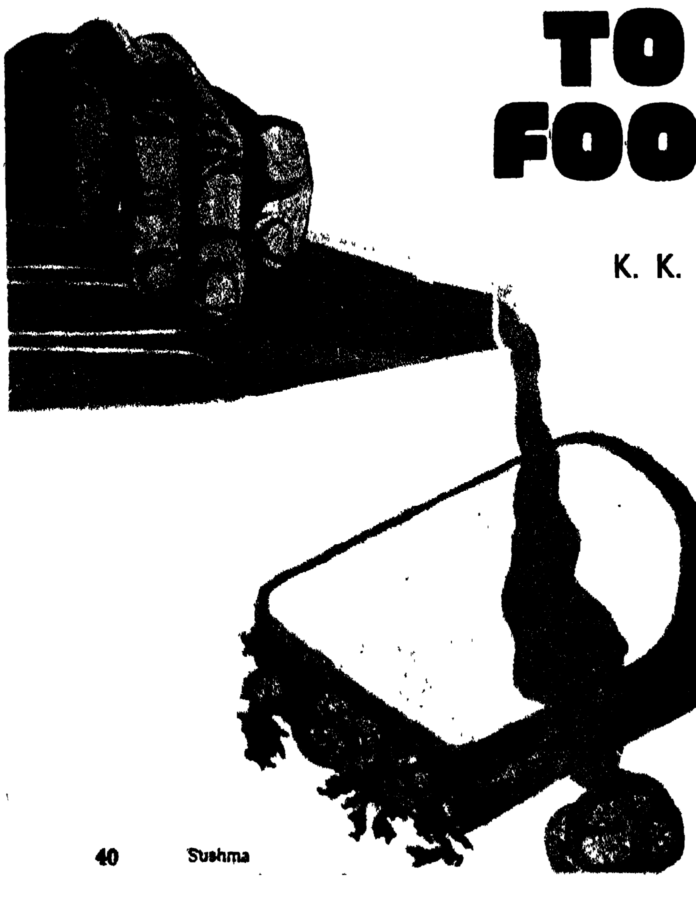
Additives serve an enormous range of functions in today's foods. Some improve the quality, taste, appearance and appeal of the food; some inhibit staling, moulding or bacterial decomposition of food; some prevent the browning and deterioration of fruits, and some improve their flavour and texture and extend their usefulness. Increasing urbanisation has necessitated transport of food over great distances and storage for great lengths of time and this, in turn, has promoted wide use of a variety of food additives as preservatives, flavouring agents, antioxidants, colourants, stabilisers, foaming agents, etc. And, then, people today increasingly go in for more 'convenient', more sophisticated, more flavourful and more exotic foods which naturally involve the use of a large number of food additives.

However, the advent of food additives has not been an unmixed blessing. Many unscrupulous manufacturers have in the past used additives to upgrade deceptively the quality of foods or have doctored foods to attract wider consumer acceptance. Several food additives, which were widely used earlier, have also been either restricted for use or prohibited as a result of better knowledge about their probable long-term effects. The list of such additives is staggering; it includes, for example, chloracetic acid for preserving wines, sulphite for reddening meat, nitrogen trichloride (agene) for bleaching flours, dulcin (4-ethoxyphenyl urea) as an artificial sweetener, coumarin in synthetic vanillin flavours, saffrole and cobaltous salts in beer, diethylstilbestrol in animal and poultry feeds and a host of food colours. The list keeps growing. While this has shaken the confidence of the public in the safety of food additives, it has also given rise to a number of scare stories and headlines in newspapers from time to time. On balance, however, the many beneficial effects of food additives far outweigh the very few instances of harm resulting from their improper, excessive or careless use.

According to the Food and Agricultural Organisation (FAO) and the World Health Organisation (WHO), a food additive is "any substance not normally consumed as a food by itself and not normally used as a typical ingredient of the food, whether or not it has nutritive value, the intentional addition of which to food for a technological (including organoleptic) purpose in the manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food, results, or may be reasonably expected to result (directly or indirectly), in it or its by-products becoming a component of or otherwise affecting the characteristics of such foods". It does not include "contaminants", or substances added to food for maintaining or improving nutritional qualities.

The main purpose of, and the only justifications for, any food additive is that: (1) it brings some benefit to the consumer, (2) it is absolutely essential technologically in manufacturing a food product, (3) it is not used to disguise faulty processing or handling techniques, (4) it does not substantially reduce the nutritive value of the food and, most important, (5) it does not pose any health hazard for the consumer. Food additives, in general, should only be used when they can contribute to the preservation of food by maintaining its nutritive quality or keeping quality or stability or improve its organoleptic acceptance (that is, its 'appeal' to the consumer). Occasionally, food additives are also used as necessary ingredients for foods manufactured for special dietary needs, for instance, saccharine for diabetics or low-calorie foods. Since safety is the prime consideration, one has to consider and carefully evaluate the benefits and risks. Equally important, such evaluations must consider not only the amounts of an additive under conditions reasonably related to its intended use but also related to its occasional unintentional 'misuse'.

It has been estimated that we use about 20,000 chemicals as food additives. Unfortunately, our ability to interpret the metabolic significance and repercussions of these materials has lagged far behind our ability to find use for them. While this has caused considerable concern over the biological safety of these materials in the long run, the prohibition of certain food additives in one country and their permitted use in others have also created a lot of confusion in the minds of consumers and legislators. And many substances, which have been commonly used with no indications of any untoward reactions, have now been questioned by researchers and found not to meet all the criteria of safety. These include turmeric, amaranth, saccharine, etc. In fact, it may be truly stated that substances which are less well-studied appear to be about the safest at the moment, and Government regulations on the subject are severely criticised by those who know them best and as widely revered by those who do not. It is fortunate, perhaps, that fashions in food additives keep changing, so that an individual is unlikely to be exposed to the same chemical over his entire lifetime.



Sushma

The whole problem of safety of additives is, in fact, very complex. And popular and sensationalised scientific articles with provocative titles do not make it any less difficult. The Food and Drug Administration (FDA) in the USA at present presumes every new substance to be hazardous unless proven safe, and the onus of proof is on the manufacturer. The position in India is similar.

The problem is, absolute safety is really an abstraction. Despite the availability of new toxicological tools, there is no way of proving the absolute safety of a material. Short of totally prohibiting a material, one has to base one's judgments on practical criteria, concentrations of the questionable chemicals present and a proper risk-benefit assessment. In assessing risk, due consideration should be given to aspects of *toxicity* — that is, the *capacity* to produce injury — and to aspects of *hazard* in use — that is, the *capacity* to do *harm at likely human* intake levels. And, then, appropriate tests must prove beyond doubt that the substance is not carcinogenic (cancer-causing) or teratogenic (that is, embryo-toxic).

But what are " appropriate " tests? There is a great deal of argument about this. How does one determine the possibility of chemical carcinogenesis? Is it just the presence of a single molecule of the putative carcinogen, or is it related to dose as in other toxicological evaluations? Has ' zero ' tolerance (the concept that any material that is toxic should be totally absent, and should not be tolerated at all) any biological relevance?

The Delaney clause in the food additives amendment in the USA (1958) states that no chemical can be added to foods if in *any amount* it produces cancer when ingested by animals or man. Supporters of the Delaney clause emphasise that " although some people claim that certain specified low levels of carcinogens are harmless, this has never been proved. We just don't know how to establish safe tolerances for carcinogens ". On the other hand, the opponents are convinced that " threshold levels of carcinogenic activity do exist and that safe levels can be determined ". In any case, there has to be " no effect " levels of carcinogens in man. Otherwise, every one could expect to get cancer eventually because every one is exposed daily to small doses of environmental and food carcinogens — background radiation, natural oestrogens, sunlight and polycyclic hydrocarbons in vegetables. I would not go into this controversy any further. Let me say, by and large, most food additives in common use

TOXICOLOGY OF FOOD ADDITIVES

Unlike drugs, food additives, are consumed by a non-targeted population, including the vulnerable groups. They are not administered under the supervision of a doctor in a specified dose for a specified time to specific individuals. Drugs are administered at biologically effective levels and are accompanied by an element of risk, which is counter-balanced by the benefit to be gained. Food additives, on the other hand, are intended to have absolutely no biological effects, except those of normal nourishment. Further, they may be consumed throughout an individual's life. And while, with drugs, one is often able to look for their specific effects and specific organ sites to notice these effects, with food additives, one cannot be selective in the histopathological examination of tissues.

In drugs, toxicity is mainly a medical problem. In foods, the problem is much more widespread, and becomes a public health issue. In the case of drugs, the physician acts as a safety barrier between the producer and the consumer; he has the responsibility of weighing any hazard against the potential benefit to the patient. With food additives, however, the consumer is not consciously aware, nor is there a mechanism to make him aware, of the potential hazards. The consumer takes it for granted that what he buys is good for him and his health and well-being is safeguarded by the " authorities ".

Because of this, a grave responsibility is placed on scientists engaged in food technological work, on industries using food additives, and on the Government and other regulatory authorities responsible for clearing food additives for general acceptance, for monitoring the levels of food additives and for controlling the proper use, quality specifications and labelling of foods. As more and more chemicals are being used in the food chain — pesticides, fertilisers, growth stimulants, preservatives, processing aids, colouring agents, thickeners, antioxidants and so on — and as we are getting more and more conscious of the harmful effects of some of these commonly used agents, the government and the regulatory agents are becoming more and more strict and exacting about scientific and toxicological data on the usefulness and harmlessness of food additives.

TESTING OF FOOD ADDITIVES

The composition of food additives, including probable impurities, the conditions and the extent of their usage, keeping in mind differences in dietary habits in different countries, their possible misuse and their biological properties in a wide range — all these factors have to be considered in evaluating the possible hazard and making a judgment on the safety in-use of a food additive. For this, besides the physical and chemical specifications of the food additives, the following biological information is sought.

Acute toxicity data by oral administration or by injection in rats, mice and one additional species. Here one has to be careful in looking for any untoward effects from the condition of the animal, by a complete and close examination of a large number of tissues.

Short-term studies, usually by feeding for 90 days in rats or mice and in an additional species for a period of at least 10 per cent of its life span. In this case, a 1,000-fold margin of safety on " no effect " levels in animals has been suggested for extrapolation of animal data to humans.

Chronic or long-term studies, usually two-year tests in rats including complete histopathological data, toxicity, fertility (in multi-generation studies) and carcinogenecity. In this case, a 100-fold marginal safety on " no effect " levels in animals has been suggested for humans.

Besides these, *metabolic effects* of the additives on various enzyme systems such as serum and tissue enzyme levels, absorpton, digestion and excretion patterns of the additive and its metabolites, etc are also necessary. These tests require sophisticated technologies and, apart from animal use facilities, a good deal of inter-disciplinary collaboration among biochemists, physiologists, histochemists, pharmacologists, electron microscopists and ecologists and analytical chemists. And in extrapolating the results of animal studies to man, the possible differences in the action of intestinal microflora and differences in metabolism between the two species as well as individual variations in the response to additives should be considered.

STEPWISE ASSESSMENT OF SAFETY OF A FOOD ADDITIVE

A. CHEMICAL SPECIFICATIONS
1 Identity
2 Purity
3 Characterisation of impurities

B. BIOCHEMISTRY
1 Absorption
2 Digestion
3 Distribution
4 Metabolism
5 Utilisation
6 Elimination

C. PROBABLE USE
1 Daily intake
2 Effects on food
3 Nature of residue
4 Possible toxic products
5 Compatibilities

D. BIOLOGICAL EFFECTS
1 Acute toxicity
2 Subacute toxicity
3 Chronic studies
4 Multigeneration studies
5 Mutagenicity, embryo-toxicity, carcinogenicity studies
6 Studies in different animals

E. HUMAN STUDIES
1 Acceptability in foods
2 Monitoring in humans in zoned distribution
3 Epidemiological information
4 Use conforming to ADI

K.K.G.M.

today do not pose any carcinogenic hazard to the best of our knowledge and experience.

Classification of food additives

The following classes of food additives are allowed in various foods: (*a*) preservatives, (*b*) antioxidants, (*c*) emulsifying agents, stabilisers and thickeners, (*d*) sequestering and buffering agents, (*e*) bleaching and maturing agents and starch modifiers, (*f*) food colours, (*g*) flavouring agents and flavour boosters, (*h*) nutrient supplements, (*i*) non-nutritive and special dietary sweeteners, and (*j*) anticaking agents.

Preservative is a " substance which when added to food is capable of inhibiting, retarding or arresting the process of fermentation or decomposition of the food ". Under the Prevention of Food Adulteration (PFA) Rules, there are two classes of preservatives. Class I are those on which there is no restriction on the quantities to be used (unless provided in the rules); Class II are those which are permitted within specified limits in specific foods and have to be declared on the labels. Common salt, sugar, glucose or dextrose, spices, vinegar, honey and edible oils are Class I preservatives. Examples of Class II preservatives are benzoic acid, methyl or propyl parahydroxy benzoic acid, sulphur dioxide, nitrates and nitrites, sorbic acid, propionic acid, lactic acid and acid calcium phosphate. When more than two Class II preservatives are used in conjunction, their individual amounts should be fixed in such a way that their total amounts do not exceed the equivalent permissible levels of each.

No doubt, preservatives are unavoidable because of the time-lag involved in taking agricultural products from the farms to the consumers' tables and to avoid wastage of food, but caution is needed in their use, particularly in foods meant for children. In adults, many of the ' added ' preservatives are metabolised or otherwise disposed of by the detoxification systems of the liver and the kidneys. Since these mechanisms are not fully developed in infants and children, one has to be particularly careful about the use of preserved foods in the dietaries of children. Benzoic acid, sulphur dioxide, sorbic acid and nitrites and nitrates are all culpable in this regard.

The case of nitrites is typical. Nitrite is primarily added to meat to produce the typical red colour of cured meat products; it has also significant preservative effect, particularly against *Botulinum*. The acute and sub-acute toxic effects of nitrites (vasodilation, lowering of blood pressure and formation of methaemoglobin, that is, oxidised haemoglobin) are well known. Treatment of green vegetables with fertilisers can result in high contents of nitrate/nitrite in leafy vegetables eaten raw. Recently there have been instances of methaemoglobinemia and death in babies in West Germany following the ingestion of spinach containing nitrates. Several foodstuffs such as fish meal, cheese and meat can contain nitrosamines produced by the reaction of nitrite with secondary or tertiary amines. Nitrosamines have been shown to be carcinogenic in a number of animals and there is a need to restrict the intake of nitrate/nitrite in diets, specially for children.

Antioxidants are " substances which when added to food retard or prevent oxidative deterioration of food but do not include sugar, cereals, oils, herbs and spices ". Antioxidants used in foods are also of two categories: Class I includes lecithin, ascorbic acid and tocopherols, for which there are no specific limits and which can be added according to the requirements of good manufacturing practices; Class II includes gallates, butylated hydroxy anisole (BHA) and butylated hydroxy toluene (BHT), resin guaiac, and citric and tartaric acids which are generally allowed in foods at specified levels. In ghee and butter, only BHA and BHT may be added. The amounts allowed range from 100 to 200 parts per million (ppm), depending on the substance. BHA and BHT have been widely used as antioxidants in foods, for instance, in oil and vanaspati. Whereas BHA is reportedly excreted in the urine, BHT is excreted very slowly and incompletely. This has led to the suspicion that BHT may be stored in the tissues; it would be better to restrict its use in food for human consumption as far as possible. In fact, BHA has been extensively permitted for use in several major countries but not BHT, though, technically, both BHA and BHT have been given temporary (or tentative) toxicological clearance for use in food by the FAO and the WHO.

Emulsifying agents and stabilising agents mean " substances which when added to food are capable of facilitating a uniform dispersion of oils and fats in aqueous media or vice versa ". A wide variety of substances have been used for these purposes — many gums, albumen, gelatine, starches, proteins and derivatives of fats and of cellulose — in products such as margarine, ice-cream, jellies and jams. Under the PFA, only certain emulsifying agents can be used in milk and milk products. In any case, no emulsifying agent can be used in a food except where its use is specifically permitted. There are no limitations on the general use of natural gums such as acacia, guar and Carob bean but there are restrictions on the permissible maximum use of other gums such as alginic acid, carrageenan and synthetic cellulose and fatty acid derivatives. The acceptable daily intakes (ADI) of a number of these substances are given in Table I.

TABLE I: EMULSIFIERS, STABILISERS AND THICKENERS

	ADI (mg/kg of body weight)
Sucrose esters of fatty acids	2·5 (temporary)
Sucroglycerides	25 (temp)
Polyglycerol esters of fatty acids	25
Polypropylene esters of fatty acids	25
Mono and diglycerides of fatty acids	Not specified
(Acetic, lactic, citric, tartaric) esters of glycerol	50
Sorbitan esters	25
Carob (locust) bean gum	Not known
Tamarind seed flour	Not known
Gum ghatti	Not known
Karaya (*Sterculia*)	Not known
Guar gum	Not limited
Gum arabic (acacia)	Not limited
Agar	Not limited
Seaweed extracts (Alginic acid)	25
Pectins, amidated pectins	25
Cellulose derivatives	25
Xanthan gum	10

Sequestering agents are " substances which prevent adverse effects of metals catalysing the oxidative breakdown of foods by forming chelates, thus inhibiting discoloration, off-taste and rancidity ". Sequestering agents commonly used in foods are citrate, gluconate, phosphates and tartarates. These occur very commonly; they do no harm when added to foods in small amounts. However, in certain foods such as canned fish and meat and carbonated beverages and dressings, ethylene diamine tertra acetate (EDTA) is being used in the USA though it is not permissible in India.

Buffering agents are used to counteract acidic or alkaline changes in foods during storage or processing; they improve flavour and increase the stability of foods. The usual buffering agents used are certain organic acids like citric, acetic, malic acids, and alkalies such as sodium hydroxide or carbonate and salts. These are generally innocuous but should not be used in manufacturing practices to deceive the consumer by providing superficial appearance of quality or colour.

Bleaching agents are used to give foods a more attractive coloration — for example, bleaching of wheat flour. *Maturing agents* are used to induce changes which would otherwise normally occur over a longer period of time; bromates, for instance, are used as dough conditioners. A number of starches are also being used nowadays in cakes and other preparations to enhance the quality and to arrest the degradation caused by fruits and other additives in cakes. In our country, the use of these materials is minimal and is not a subject of public concern.

Food colours

In India, the addition of colouring matter to any article of food except as specifically permitted by the PFA rules is prohibited. Also, the colouring agent added has to be clearly mentioned on the label. Caramel made by other than the ammonia process may be used without label declaration, but caramel made by the ammonia process can be used only in quantities less than 2,000 ppm in foods. The natural colours and the synthetic colouring matters which may be used in foods in India are given in Table II.

In the use of colours, as in the case of other food additives, different countries arrive at different conclusions on admissibility and use. Each of these conclusions may be right from the individual country's point of view, but it definitely confuses the consumer — he does not understand why he is eating something that is banned in another country. For example, Red No. 40 (Allura Red) is used in the USA but is not permitted in Canada. Green S is not permitted in the USA but is allowed in the UK and India. Quinoline Yellow is allowed in the UK and Germany but not in the USA and India. Ponceau 4R is allowed in the UK and India but not in the USA. There are quite a few colours such as Indanthrene Blue RS, Patent Blue 5 and Ponceau 6R which are allowed in other countries but not in India. We also put a general limit of 0·2 per cent for aromatic amines in synthetic colours.

Amaranth (FD & C No. 2) is one of the most widely used colours. It has been recently banned in the USA, but is permitted in Canada and the UK. There has been some concern over the carcinogenicity and teratogenicity of amaranth based on Russian observations that it caused foetal damage in rats. Subsequent experiments have failed to produce unequivocal results — particularly those on teratogenicity recently carried out by the FDA and the National Center for Toxicological Research in the USA. The overall view seems to be that so far data concerning the potential hazards of this colour have not been definitive and do not justify prohibiting or restricting its use. Before the recent ban in the USA, they were using more than half a million kg of this colour per year. The concern over carcinogenicity and teratogenicity due to amaranth appears to have arisen from the use in animal tests of samples of amaranth with specifications different from those established by the (US) FDA.

The FAO/WHO temporary acceptance for daily intake of 2·5 mg per kg body-weight of turmeric works out to only about 150 mg of turmeric per 60-kg man per day or approximately 1·5 to 2 g of curry powder per day. These figures appear to be too conservative as many people in India take much larger amounts of turmeric and there have been no reports yet of any untoward effects.

ACCEPTABLE DAILY INTAKE OF FOOD ADDITIVES

The enzyme systems for the metabolism and disposal of chemicals added to food are not fully developed in infants and children. This demands particular caution in permitting food additives in foods for infants and children. Therefore, irrespective of the indicated acceptable daily intake (ADI), food additives are not necessarily cleared or automatically permitted in children's foods.

The acceptable daily intake in the FAO/WHO recommendations are given in terms of mg/kg body-weight, but when one converts it in terms of acceptable concentrations in foods, one runs into several difficulties. For example, the ADI in terms of mg/kg body-weight should not be considered in terms of a 70-kg man. Most of the people in India are of lower weight; the total intake should, therefore, be correspondingly less. Also, persons with lower body-weights may consume the same amount of food as a 70-kg man. Hence, the transfer of ADI values to acceptable maximum foods must be a conservative estimate. Besides, regional differences in eating habits are obvious obstacles to establishing worldwide standards for permissible levels of food additives.

Since risk is a product of toxicity and exposure, it would be high when the degree and time of exposure are high. Hence, the potential daily intake of a food is of great relevance in considering the ADI of the additives. For example, the ADI of benzoic acid is 5 mg/kg or 300 mg for a 60-kg man. Fruit drinks and beverages, beer, pickles, tomato sauce, minced meat and a number of other foods contribute to one's intake of benzoic acid. In India, our normal dietary habits preclude a high ingestion of tomato sauce and, therefore, the amount of benzoic acid permitted is 450 ppm in tomato sauce. However, in European countries, tomato sauce is used more widely and the benzoic acid levels permitted are lower at 250 ppm.

The ADI can also be related to the caloric content of foods and caloric intakes. Since the highest caloric intake per kg body-weight is 100 cals/day (which is the intake of a one-year-old baby) ADI per kg body-weight can be taken to be equivalent to ADI in mgm for 100 calories. If higher levels of use are required, the additive in question should be either reserved for specific foodstuffs not commonly used or for specific dietary situations. Otherwise, the possibility whether the additive can be replaced by a less toxic substance or whether the same technological effects can be obtained in smaller amounts in combination with other additives should be examined.

K.K.G.M.

Flavouring agents produce a predominant odour, which possibly affects taste as well. Flavours may be natural or artificial. In India, flavouring chemicals are not expected to be added in foods in amounts exceeding 300 ppm. Two flavouring agents, coumarin and dihydrocoumarin, are totally prohibited. Certain substances such as quinine, agaric acid, hydrocyanic acid, solanine and saffrole, which occur either naturally in food or are added to foodstuffs are allowed only in very small amounts (1 to 10 ppm except for quinine which is allowed up to 300 ppm in alcoholic beverages). The FAO and WHO also specifically prohibit the use of any part of the following plants: (1) liverwort, (2) deadly night-shade, (3) Lily-of-the-Valley, (4) sassafras, and (5) roots of the pomegranate tree, to mention only a few.

Because the number of flavouring agents used in foods is so vast, most countries find it impossible to enumerate, classify and establish permissible levels of their usage based on toxicological data. Such data are not available for most of these compounds. Most countries, therefore, have a list of prohibited flavouring agents rather than a list of permitted ones, though the European Economic Community (EEC) and the USA are working towards the preparation of a list of permissible flavouring agents. The recent EEC list contains 495 natural flavouring substances, 692 artificial flavouring substances which may be added to foodstuffs without hazard to public health, 284 artificial flavouring substances which are permitted to be added *temporarily* to foodstuffs without hazard to public health, 243 artificial flavouring substances *not* *fully evaluated so far*, and three substances which are prohibited from all foods and flavouring agents. And this is only a beginning.

The Flavour Extract Manufacturers' Association in the USA has prepared a list of substances which are " generally regarded as safe " (GRAS). This list includes all flavouring ingredients used by the industry prior to 1958 and considered by them as safe, based on their common use in food and conditions of use. A scientific literature review of flavouring substances in the GRAS list is being undertaken by the Federation of American Societies for Experimental Biology (FSEB) under contract from the FDA. The FSEB will recommend the priorities to be used in the testing of more than 2,000 flavouring substances and run them through three tiers of test: (1) screening by bacterial or other mutagenic screening systems; (2) those found mutagenic in the initial screening test will undergo a second tier of test involving assays in mice and fruit flies; and (3) those which are inculpated in the first two sets would be subjected to largescale animal testing. This mammoth operation involves taking a toxicological view of more than 400 direct food additives and perhaps up to 10,000 indirect food additives. The concern over the largescale use of various types of food additives has been recently exacerbated by the finding that a number of these additives including flavours and colours caused hyperkinesis (uncontrollable muscle movement) in children.

Yet, many manufacturers are unwilling to disclose the constituents of their flavour extracts, let alone their composition. One of their arguments is that none of these ingredients will be used in high quantities to be of any toxicological hazard because of the self-limiting characteristics of flavour addition in food. However, multiple introduction of some of these additives in several products should be more fully evaluated and a total view taken about the permissibility or otherwise of specific flavouring agents. Among the flavouring agents to be considered with reservation are strawberry aldehyde (ethyl methyl phenyl glycidate) and chloroform. Also, it has been found that many flavouring agents are used in quantities more than 500 ppm in a single food category. These include oils of anise, grape fruit, lemon, lime, orange peel and peppermint, vanilla extract, cinnamaldehyde and methyl salicylate. The National Academy of Sciences/National Research Council in the USA have listed a wide variety of spices, herbs, essential oils, plant extractives and synthetic flavours used in processed foods, for which no formal toxicological data are available. In India, the use of these flavouring materials is limited and there is no serious cause for concern on this account. The WHO/FAO are processing data on ADI and maximum levels of use of commonly used flavouring agents, but it would take at least 10 years to collect data for even the most widely used ones.

TABLE II · COLOURS

Natural colours	ADI (mg/kg)	Maximum level permitted	Comments
1. Caramel			
Non-ammonia process	Not limited	Limited by GMP	
Ammonia process	100 (temporary)		4-methyl imidazole not to exceed 200 mg/kg
2. Annatte	1·25 (temporary) (as Bixin)	300 mg/kg	
3. Carotenoids	5	Limited by GMP	
4. Chlorophyll	15	Limited by GMP	
5. Turmeric	2·5 (temporary)	Limited by GMP	On the basis of 3% curcumin in turmeric
Curcumin	0·1 (temporary)		
6. Riboflavin	0·5	Limited by GMP	
7. Saffron	na**	na**	

* Good manufacturing practice ** Not available

Synthetic colours	Common name	ADI (mg/kg)	Maximum level permitted	Comments
1. Red	Ponceau 4 R (Food Red 7)	0·75 (temporary)	30–300 mg/kg in different foods	
	Carmoisine (Azorubine)	0·5 (temporary)		
	Amaranth	0·75 (temporary)	30–200 mg/kg in different foods	
	Erythrosine	1·25 (temporary)	30–300 mg/kg in different foods	[illegible]
2. Yellow	Tartrazine	7·5	30–200 mg/kg in different foods	
	Sunset Yellow FCF	5	30–200 mg/kg in different foods	
3. Blue	Indigo carmine (Indigotine)	2·5 (temporary)	200 mg/kg	
	Brilliant Blue FCF	12·5	100–200 mg/kg in different foods	
4. Green	Green S	5 (temporary)	100–200 mg/kg in different foods	
	[illegible] Green FCF	12·5	200 mg/kg	

The flavour enhancers widely used in the food industry are maltol (ADI 1 mg/kg), ethyl maltol (ADI 2 mg/kg), glutamic acid and its salts (ADI 120 mg/kg, additional to intake from dietary sources) and nucleotides. Monosodium glutamate has been widely used as a flavour enhancer for meat. Recently, some doubts have been raised on the harmlessness of glutamate, based mainly on the work of Olney and Sharpe in the USA who found that subcutaneous injection of monosodium glutamate in newborn monkeys produced lesions in the periventricular region of the hypothalamus of the brain. The " Chinese restaurant syndrome " characterised by a tingling sensation and a flushed feeling due to high ingestion of monosodium glutamate-containing food was also noted. Hence the WHO/FAO's recommendations on ADI for monosodium glutamate do not apply to infants under 12 weeks of age, and the addition of the substance is not allowed in the diet of infants. In any case, babies may be far less sensitive to taste than are adults. In most countries, there is a voluntary ban on the use of glutamate in baby foods as well. Glutamic acid is a normal constituent of all proteins, and the average adult daily consumption of glutamic acid from food proteins is estimated to be of the order of 15 gm. Since the average daily intake of monosodium glutamate is of the order of only 200 mg, it may be stated with reasonable assurance that glutamate as an additive to foods is unlikely to cause any harmful effect. In India, the following levels of acceptance are being considered: glutamate not more than 500 ppm in soups and meat foods for adults; maltol — not more than 325 ppm in biscuits, chocolates and baked foods; and ethyl maltol — a maximum of 600 ppm in biscuits, chocolates and baked foods.

The following solvents in flavours are generally permitted: ethyl alcohol, propylene glycol, glycerol, isopropyl alcohol food grade, acetic acid and propanediol. Solvents such as diethylene glycol monoethyl ether, 1-2 dichloroethane, hexylene glycol, 1-1-2 trichloroethylene and diethyl ether are specifically prohibited.

REGULATIONS

In India, food additives come under the provisions of the Prevention of Food Adulteration Act, 1954 (Act No. 37 of 1954). It comes under the purview of the Health Ministry. A committee, called the Central Committee for Food Standards advises the Central and State governments on matters relating to the setting up of standards and administration of this Act. It also carries out other functions assigned to it under this Act.

In the USA, the Federal Food and Drug Administration is the authority responsible for ensuring the safety of food additives. It sets the necessary specification for the product and, in most cases, establishes specific tolerances. In the UK, the Ministry of Agriculture, Fisheries and Food and the Ministry of Health are jointly responsible under powers conferred on them under the Food and Drugs Act, 1955.

In the UK, the British Industrial Biological Research Organisation at Carshalton, Surrey, evaluates all food additives used by industries and also provides information on the current development in food additives legislation in various countries. There is a need in India for a similar organisation to review and canalise work in this area and provide information to all industries and various departments of the Government. There is also a need to study and evaluate several of the additives commonly used in India. At the moment, not much research work is being done in food additives and the standards are taken from studies done abroad. K.K.G.M.

A number of *nutrient supplements* such as various vitamins, amino acids, minerals and essential fatty acids are also permitted in judicious amounts in most foods. Many manufacturers of ready-to-eat breakfast foods add thiamine, riboflavin, niacin and iron on a voluntary basis. These are meant to produce products containing nutrients in quantities corresponding to those in the cereals from which the foods are made. Also, vitamin A is usually added to vanaspati and margarine, potassium iodide or iodate in common salt and vitamin D in certain milk products. Many calcium and iron salts are added as mineral supplements in a number of food formulations. Lysine is used to fortify bread and cereal mixes and many trace elements like zinc, copper, cobalt, molybdenum, etc are added in some mineral mixes in human and animal nutrition.

Of the non-nutritive *sweeteners*, saccharin is the most widely used, with an ADI of 5 mg/kg for common use and up to 15 mg/kg for dietary purposes for diabetics. Permission for the use of cyclamate has been withdrawn. Sorbitol is allowed as a non-nutritive sweetener in foods, the maximum permissible levels being limited by good manufacturing practice.

Though the use of cyclamate has been banned, earlier fears about the carcinogenic potential of cyclamate has been shown to be groundless. Both cyclamate and cyclohexylamine gave negative results in the new Ames test for mutagenicity. This supports the view that they are non-carcinogenic: there is no justification, therefore, to classify cyclamates as carcinogens. However, there are other genetic questions raised by cyclamates, [illegible] Down's syndrome and testi[illegible] reproductive results in test [illegible]h establish a cyclamate [illegible] low to permit the use of [illegible] material as an artificial sweetening agent. Saccharin, unlike cycla[illegible] metabolised either in [illegible] animals or in man, but [illegible] excreted unchanged. There have been no serious challenges to its use on toxicological grounds. However, there is a limit of 100 ppm on the amount of orthotoluene sulphonamide (OTS) in saccharin.

Recent Canadian studies have shown that saccharin " can produce malignant bladder tumour in rats " and the Department of Health and Welfare in Canada has banned [illegible] use in foods on the basis [illegible] results. But, OTS, an i[illegible] saccharin, which had previously [illegible] incriminated as a carcinogenic factor, was shown to be non-carcinogenic in these Canadian tests. [illegible] USA has taken [illegible] necessary to issue a total ban on the use of saccharin in foods citing Canadian " definitive " data indicting saccharin as a potential carcinogen. However, no similar action has been taken in the UK and in other European countries.

There has been a chorus of attack on the FDA on the ban on saccharin since Americans consume over 3 million kg of saccharin every year and millions of people use it in dietetic foods, especially for the control of diabetes and obesity. To complicate matters, pure saccharin is not mutagenic in the Ames test (a sensitive in vitro test for screening cancer-producing substances). Further, many scientists point out that when it comes to bladders, rats are a special breed, which concentrate their urine to a very high specific gravity. This means that the chemicals in the urine are apt to remain in the bladder for comparatively long periods before being excreted. Suggestions have been made, therefore, that saccharin should be tested in other species.

The FDA in the USA may insist on the enforcement of a ban on saccharin in foods but may re-classify it as an over the counter (OTC) drug on the basis that it is efficacious for medicinal purposes. However, the ban on saccharin has given an impetus to the search for alternative sweeteners. These include: (*i*) talin, a substance about 2,000 times as sweet as sucrose, produced from the seeds of the fruit of *Thaumatococcus daniellii*, which grows wild in West Africa; (*ii*) xylitol, a naturally occurring sugar with about the same sweetness as sucrose; (*iii*) aspartame, a dipeptide sweetener; (*iv*) acetosulpham, a substance 250 [illegible]; (*v*) cyclamates, which were at one time used as sweetening agents and were later banned (further evidence for its biological safety is being considered by [illegible] chalcones, [illegible] orange rinds, which have been shown to have lingering sweetness.

Anticaking agents are added either in the processing or in the manufacture of foods to produce effects like free flow or freedom from caking. The substances added include carbonates or phosphates of calcium or magnesium, silicates of calcium, magnesium, aluminium or sodium, silicon dioxide, myristate, palmitate or stearates of aluminium, ammonium, calcium, magnesium, potassium or sodium. These are added only when they are deemed absolutely essential.

An international appraisal of food laws pertaining to additives is essential for continued public health protection and understanding and anticipation of problems of import and export of foods. Regulations in this area have always come out easier against something, rather than for something. But there are no two opinions on the beneficial role of food additives in enabling man to extend and vary the quantum and kind of food available and make it more presentable and acceptable.

Dr. Menon heads the Hindustan Lever research group in Bombay. He is on the Central Committee for Food Standards, and is also associated with several committees of the Indian Standards Institution and with dairy research in India.

Recommends reading: **1.** Furia, T. E. (ed) 1972 *Handbook of Food Additives* (2nd ed) CRC Press, Ohio, USA. **2.** National Research Council, USA, 1965 *Chemicals Used in Food Processing*, Publication 1274, Washington DC. **3.** Council of Europe 1973 *Natural Flavouring Substances, their Sources and Added Artificial Flavouring Substances*, Strasbourg. **4.** Sanders, H. J. 1966 Food additives *Chem. & Eng. News* (Oct. 10 and Oct. 17). **5.** Menon, K. K. G. 1972 Problems of Food Additives and Contaminants *Proceedings of the First Asian Congress of Nutrition* Nutrition Society of India, National Institute of Nutrition, Hyderabad. **6.** Govt. of India *Prevention of Food Adulteration Act and Rules* Ram Narain Lal Beni Prasad, Law Publisher, Allahabad.

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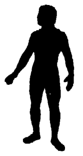

Protein
Carbohydrate
Calcium
Lipids
Phosphorus
Sodium
Chloride as (Cl)
Potassium
Iron
Iodine
Vitamin A
Vitamin B_1
Riboflavine
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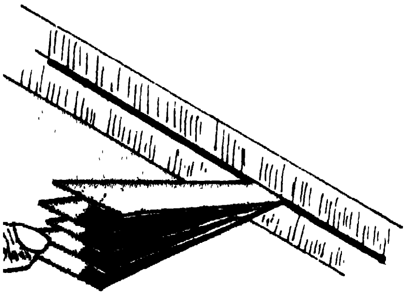


Fig. 1

It used to be a rather common scene in the old Western movies: Red Indian scouts would fall to their knees and press their ears to the ground to detect the hoofbeats of distant, unseen riders. Now, why couldn't they hear the hoofbeats through the air? After all air is the medium through which sound vibrations are carried to the listener. Well, before we answer the puzzle, let's take a look at the phenomenon of sound.

When a body vibrates, it produces vibrations in the air column around it and produces sound. Stick a razor blade into a slit at the side of a table. Strike the free end. As the blade vibrates, you can hear a buzzing sound. Sound propagates in the form of waves and these waves travel in all directions like water waves when a stone is dropped in still water. Sound waves travel through the medium of air and reach our ears.

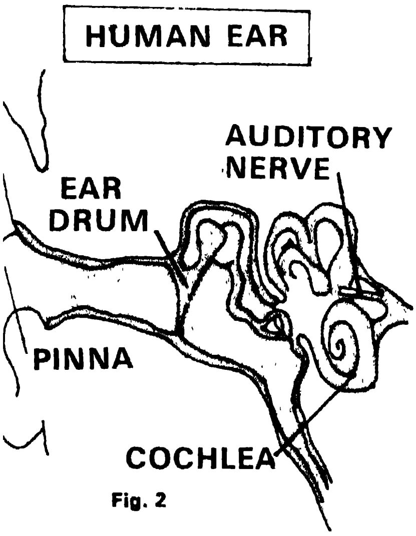
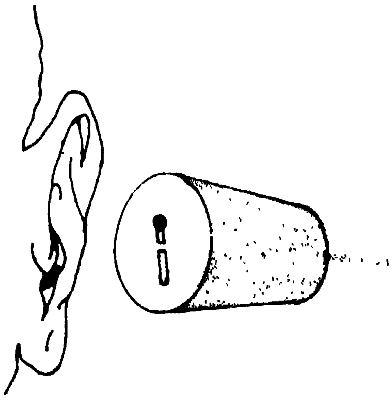


Fig. 2

The human ear is one of the greatest wonders of nature. It can detect and differentiate between sounds within an enormous range of frequency (from 20 to 20,000 Hertzs, or cycles per sound). The sound waves are collected at the outer ear called *pinna* and carried through the channel to the ear drum and set it vibrating. The ear drum transmits the vibrations to the inner ear called *cochlea*, through a chain of three bones. In the cochlea, nerve endings are stimulated and carry messages to the brain indicating the rate of vibration in the inner ear and we thus hear a note of appropriate pitch.

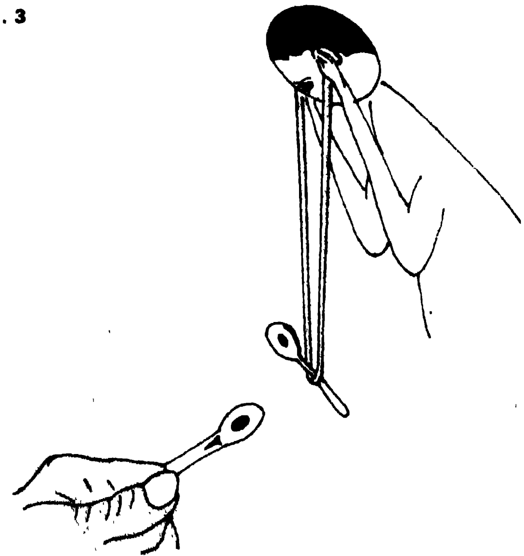
But, then, while sound waves are principally vibrations in the air, they can also be vibrations in water, wood, metals, and the ground, too. Actually, sound waves are conducted more readily through these things than through the air. So, now we have the answer to the puzzle why the Red Indian scout would put his ear to the ground to hear the distant rider!



How about some practical demonstrations? Place your ear tightly on to a table and ask somebody to tap on the table some distance away with a spoon. The sound would reach your ear like a loud 'bang'; through air, it would be carried to your ear merely as a 'tap'. Try another experiment: hold a wrist watch tightly between your teeth and close both ears tightly with the palms of your hands. You can now hear the ticking much more loudly.

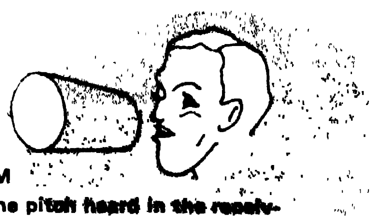
Even a string will transmit sound vibrations much better than air. Tie a spoon at the middle of a metre-long string and hold both ends of the string tightly to your ears (Fig. 3); bend forward a little so that the spoon hangs freely. Ask a friend to beat the spoon with another one. The sound will reach your ears like the 'gong' of church bells!

Fig. 3



Now you can understand how toy 'string telephones' work. Let's make one. It's very simple really. We need two empty tins and several metres of thin string. Punch a hole at the bottom of each tin, pass one end of the string through and tie it with a matchstick. Ask your friend to pull the string taut and speak into his tin. Hold your tin to your ear and you can hear him quite distinctly (Fig. 4).

Fig. 4



PROBLEM

Does the pitch heard in the receiving can depend on the tightness and density of the string, and the size of the can?

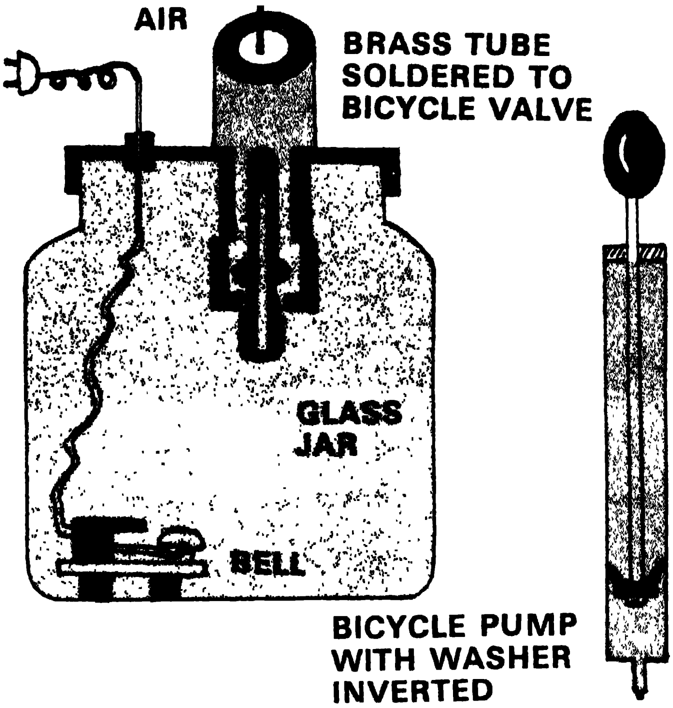

AIR
BRASS TUBE SOLDERED TO BICYCLE VALVE
GLASS JAR
BELL
BICYCLE PUMP WITH WASHER INVERTED

Fig. 5

Fig. 5 shows an experiment that proves the most important property of sound. Let's get an electric bell, a glass jar with air-tight lid and a vacuum pump. (You can use a bicycle pump by inverting the washer inside.) Place the bell inside the jar and take the wires out through the lid. Take a bicycle tube valve unit and fix it on the lid in downward direction. Switch on the bell and you can hear it ringing. Now, slowly take out the air inside the jar by using the pump. The ringing sound becomes fainter as you go on creating vacuum in the jar. When, there's no more air left in the jar, you will hear no ringing. Why does it happen?

We have seen that sound requires a medium through which to travel to reach our ears. How about proving the waves are transferred onwards in all directions? We shall need a tuning fork (Fig. 6a) for that. Since it is difficult to come by a professionally made tuning fork, we can make one from a mild steel bar (1 cm square, or 1 cm diameter if rounded) (Fig. 6b). Hang a table-tennis ball from a string. Hold the fork lightly and then hit it against wood. The fork will produce sound. Now, if you bring the fork close to the ball, you'll find the ball, too, vibrates!

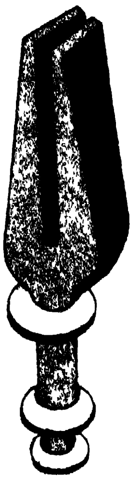
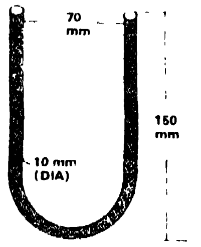


Fig. 6a The tuning fork. The instrument, which when struck gives a note of accurate pitch, was invented by John Shore, a trumpeter at the Chapel Royal in London, in 1711

Fig. 6b



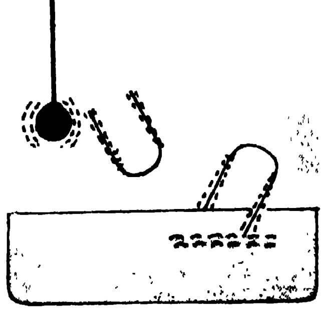
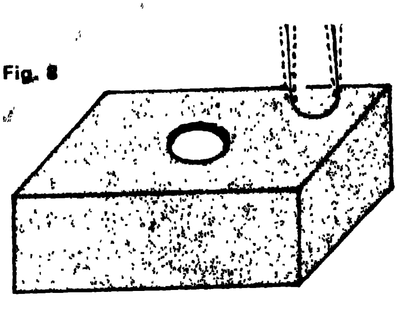


Fig. 7

Fig. 8



Again, if you take a tub with water and dip the vibrating (after impact) fork, waves will appear on the water's surface (Fig. 7). And, then, a vibrating body will produce more sound if it comes into contact with another body of larger surface. Hold the tuning fork (after impacting) on a hollow box closed on all sides except for a hole at the top (Fig. 8). How does the sound come out?

How often have you held a rubber band between your teeth, stretched it and played on it? Must be many, many times. But, how often did you notice the difference in the pitch of the 'twang' sound depending on how far you stretched the band?

Fix a nail at one end of a wooden board (60 cm × 15 cm × 1 cm size) and tie a metre-long steel wire to it. Place a wedge near this nail and at the other end of the board, place a wooden cylinder between four nails. Take the wire over the wedge and the cylinder and hang a weight at its free end (Fig. 9). Play the steel wire with your finger. Repeat the experiment with different weights (that is, different degrees of tautness) and different lengths of wire (that is, by moving the wedge). You will notice a higher note comes out as you increase the tautness or reduce the length of the wire.

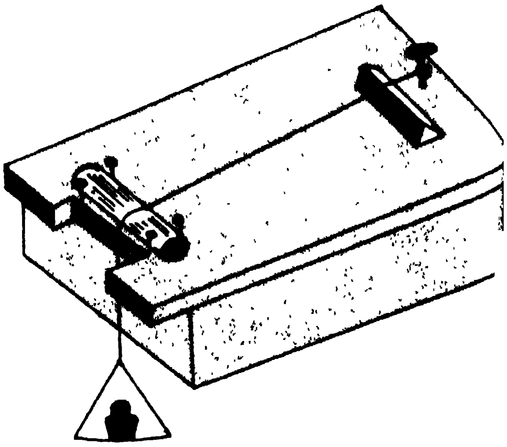


Fig. 9

Resonance

If you know somebody who has a pair of violins, ask him or her to set their wires to tune identically. Place the violins side by side. Now strike the wires of one violin; the wires of the other will start vibrating. How does it happen?

Fig. 10

The answer lies in 'resonance'. Every vibrating object has its own natural frequency of vibration. If sound waves having the same frequency are allowed to act upon it, it will vibrate in sympathy with the sound waves. This is known as resonance. We can demonstrate this with two identical tuning forks (Fig. 10). Fix the tuning forks each in a hollow box and then place the boxes side by side. Hit one tuning fork with a rubber hammer, allow it to vibrate for a moment and then stop it by touching the prongs with your fingers. The other fork will be found vibrating due to its resonating frequency.

Figs. 11, 12 and 13 show how to make some musical toys — a toy-violin, a ding-dong bell (like a Japanese wind-chime), and a xylophone!

TOY VIOLIN

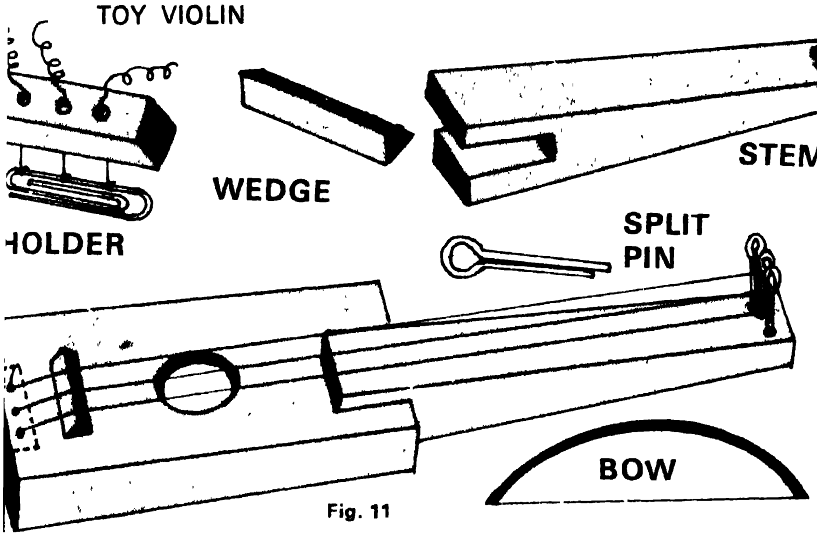


Fig. 11

We need a cigar box, two wooden pieces, a wooden batten, regular musical strings, bamboo-stick (20 cm long) horsehair and three split pins. Cut a slot in the batten and fix it on to the cigar box (using a strong adhesive). Cut a 2·5 cm diameter circular hole in the box. At the other end of the batten drill some holes for the split pins. Take a small rectangular piece of wood, drill three holes for wires to pass through and screw it on to the other end of the cigar box. Pass the strings through the holes and secure by tying knots or winding the ends on a paper clip. Tighten the strings by means of the split pins. Take a triangular piece of wood (1 cm × 1 cm × 4 cm) to make the bridge (wedge).

Bend the bamboo stick and tie with horsehair to make a bow. You can tighten or loosen the strings by turning the split pins.

If you are musical and have the aptitude, you might even be able to play some tunes on it.

DING-DONG BELL

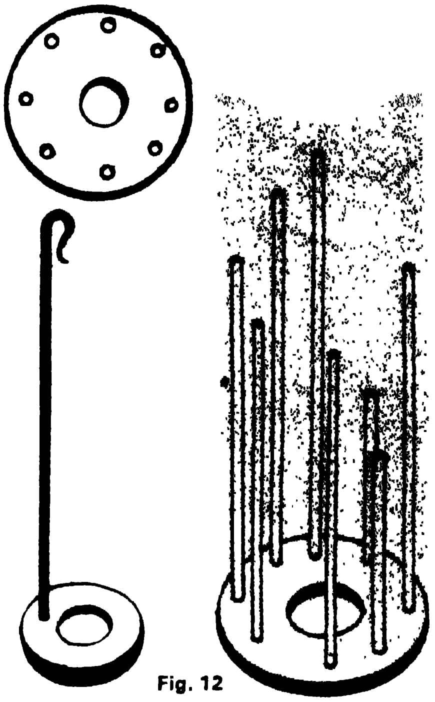


Fig. 12

We shall need a thick metal washer (5 cm dia and 5 mm thick) and hard steel wire (1·5 mm dia). From the steel wire, cut eight pieces of 4 cm to 11 cm length (each longer by 1 cm). Drill eight holes of 1·5 mm diameter near the outer edge of the washer. (You may have to make use of workshop machinery for this toy.)

Fix the wire pieces tightly in the holes. Now prepare a cardboard cylinder (about 13 cm long) with the bottom closed and place the washer (with the standing wires) at the bottom. Now we need a beating hammer. Take another washer of 2 cm diameter and drill a 15 mm hole in it. Fix a wire length (10 cm long) into it and turn the other end into a hook and hang it from soft wire from the open end of the cylinder.

Hold the cylinder and tilt it in different directions; as the 'beating hammer' strikes the different wires, you can hear the sound of different musical notes.

XYLOPHONE

You can use either wooden strips (2 cm wide and 1 cm thick) or mild steel flat (3 cm wide and 2 cm thick). Cut eight pieces of 8 cm to 15 cm long, with increments of 1 cm. Drill 3 mm-diameter holes at both ends of each strip. Take two battens (4 cm × 1 cm × 25 cm), lay strips of felt or satin cloth on them and place the strips by driving nails through the holes to hold them *loosely*.

Prepare two wooden strikers. As you tap the strips with them, you have a rather sweet-sounding xylophone.

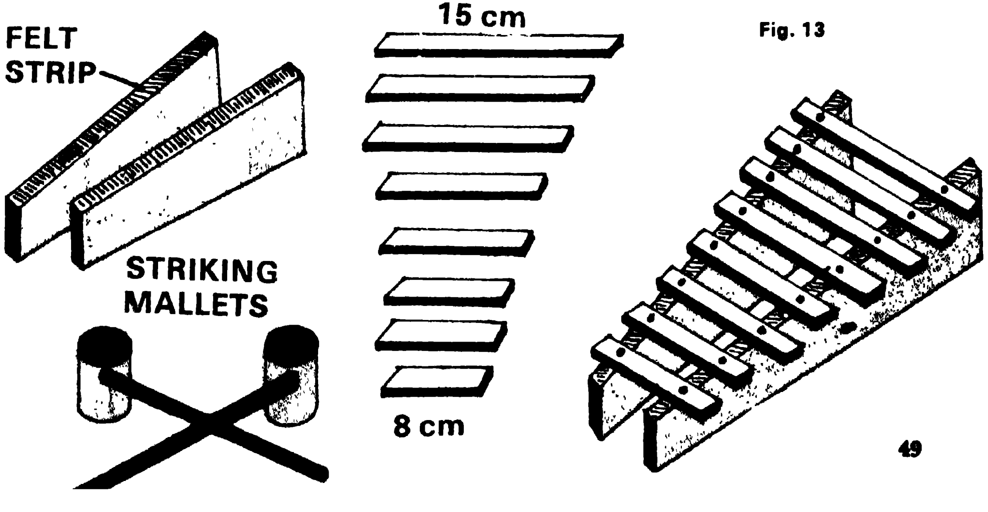
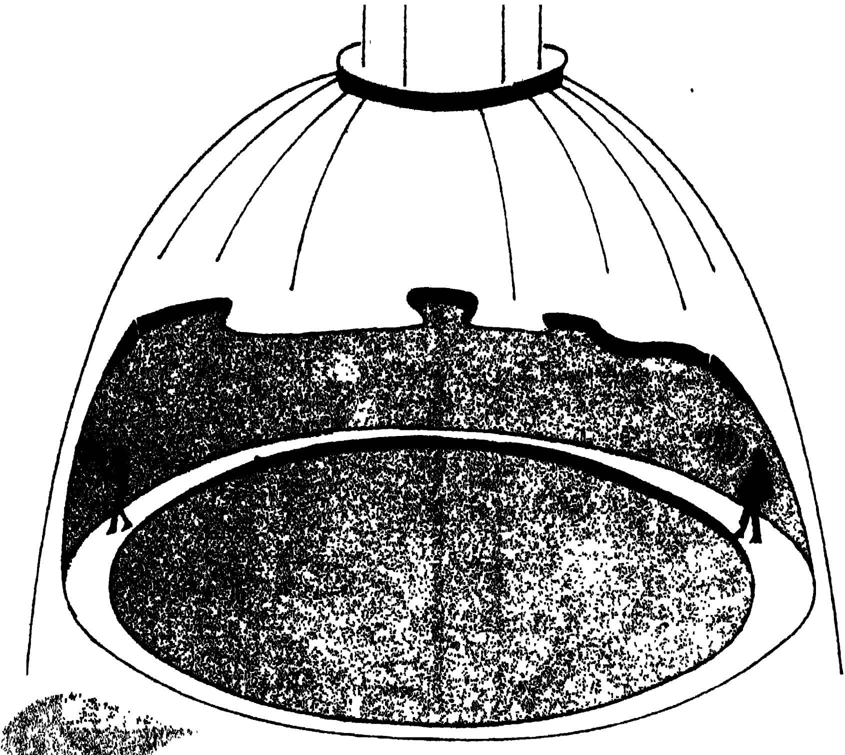


Fig. 13



Whispering galleries

Some rooms are noted for their strange acoustics; some even provide a focusing of the sound. It's said, the dungeons of Syracuse were built in such a way that the jailors could hear every conversation and even whispers of the prisoners; it was called the " Ear of Dionysus ". The story goes, the dome of the old Hall of Representatives in the Capitol building at the US capital had a similar reflecting capacity; even a whisper from one side of the chamber would be heard on the other side and had embarrassed many a member on more than one occasion.

In the dome of London's St. Paul's Cathedral, there is a " whispering gallery " If somebody whispers *to the wall* anywhere in the gallery, one can hear the whisper no matter where one is standing along the gallery. And, strangely, the more the whisperer faces the wall and is closer to it, the better the sound reproduction. Is this just a matter of reflection and sound focusing? The British physicist Rayleigh had built a model of the gallery to find out why it occurs. At one end he placed a ' bird-call ' whistle and at the other end, a candle. When sound waves from the bird-call reached the candle, the flame flickered. So there was the answer, wasn't it? It wasn't so simple really. When Rayleigh inserted a screen at some intermediate point (see Fig. 14), the flame didn't flicker. Why not? After all, the screen was placed along the perimeter, far out of the direct path of the sound wave to the candle! Well, Rayleigh did find his answer and, hence, a clue to the nature of a whispering gallery. Can you work it out?

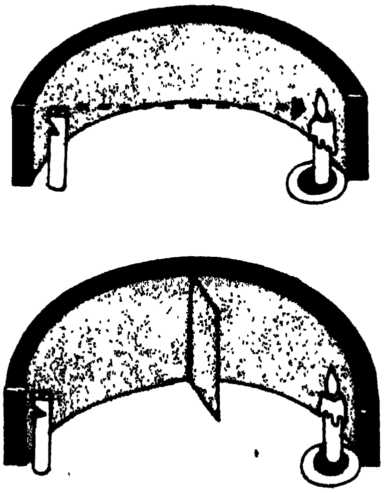


Fig. 14

In Bijapur in Karnataka, there's a building named "Gol Gummat " with a 33 metre diameter dome roof. If you stand in the gallery and shout, you will hear the same sound repeated seven or eight times. In other words, you hear ' echoes '.

Echoes are reflected sound waves. Stand some distance away from a building and facing the wall, give a shout. You hear a similar shout coming from the wall. Now, we know the speed of sound waves: they travel through air at 330 metres per second. So, if you can time the echo of your shout, you can calculate the distance to the wall. When you see lightning, count the seconds before you hear thunder. You can then tell how far the lightning was by multiplying 330 m by the number of seconds taken to hear the thunder!

Echoes are reflected sound waves. When multiple reflections occur, they are called reverberations. Take a hollow cylindrical paper roll, 5 to 6 cm in diameter, and about one metre long. Ask somebody to speak at one end as you hold your ear close to the other end. You will not be able to hear a clear speech but warbles with multiple reflections of sound waves (Fig. 15). This phenomenon of reverberation is generally experienced in large auditoriums and under bridge arches.

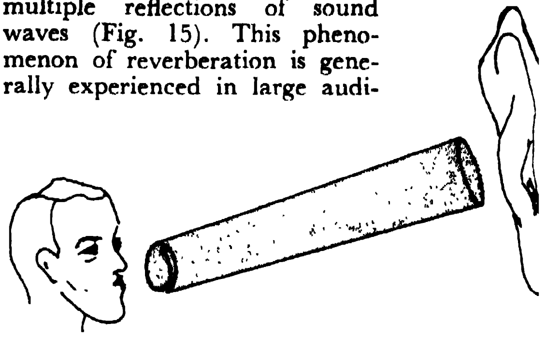


Fig. 15

SOUND
WAV

In fact, the phenomenon of sound is so intricate that we cannot hope to cover all its aspects in this very elementary discussion. For instance, there is the ' Doppler effect '. If you stand on a railway platform and carefully listen to the whistle of a fast approaching train, you will feel the sound of the whistle is a little loud as the train approaches, but it is lowered immediately after the engine passes you. When the source of sound, or the listener (or both), is moving towards the other, the listener will encounter the sound (from the source) a little faster than if both were stationary. The apparent frequency is increased and hence the listener hears a pitch slightly higher than the pitch emitted by the source.

Let's end this discussion on sound with a small poser: if you have ever recorded your own voice on a tape recorder, why is it that your voice on the tape *always* sounds a little different from what it sounds to you normally?

●●

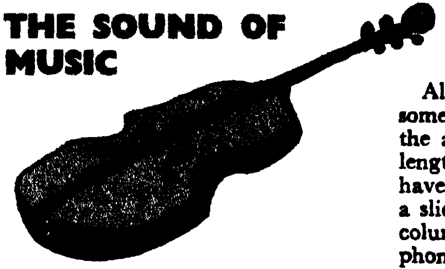
SOUND REPRODUCER

Here's a crude toy 'record player' that you can make. Take an empty match box and remove the inner container. Cut out the base and fix a thin tracing paper on it. Take a tin foil and bend it so that it touches the diaphragm as well as a needle fixed into a side of the container. Cut a small circular hole in the outer match box cover. Insert the container into the box.

Now prepare a record player using two wooden discs of 20 cm and 5 cm diameters, respectively (and 1·5 cm thick). Cut grooves on their edges for holding the cord to drive the pulleys. An additional pulley may be used to keep the cord taut.

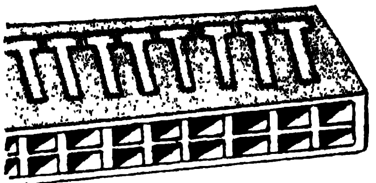
Rotate the disc by a handle and the record disc will rotate. Get an old, thrown-away record (it's better not to use a good one), place it on the turn-table and gently hold the pick-up on the record. You can hear the music! (An alternate pick-up made by rolling paper into a cone is also shown in the diagram.)

THE SOUND OF MUSIC



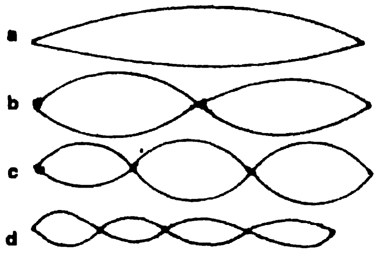
If you look at a violin or cello closely, you will notice the strings that produce low notes are thicker than those producing high notes. Also, the higher-note strings are pulled more taut. Instrumentalists use their fingers to make the strings 'shorter' (and produce a higher note). Pianos and harps have a string for each note: the strings for the low notes are long, thick and kept less taut; those for the high notes are short, thin and tight.

What about wind instruments? If you remove the cover of a mouth-organ, you can see strips of metal, called reeds, that vibrate to produce sound as air is forced past them. The longest reeds are the easiest to blow and give the lowest notes. In some instruments, sounds are produced by vibrating air columns. Blow over an empty bottle. Add some water to the bottle and blow again. Repeat with varying water levels. Each time water is added, the column of vibrating air becomes shorter and the pitch of the note is higher.



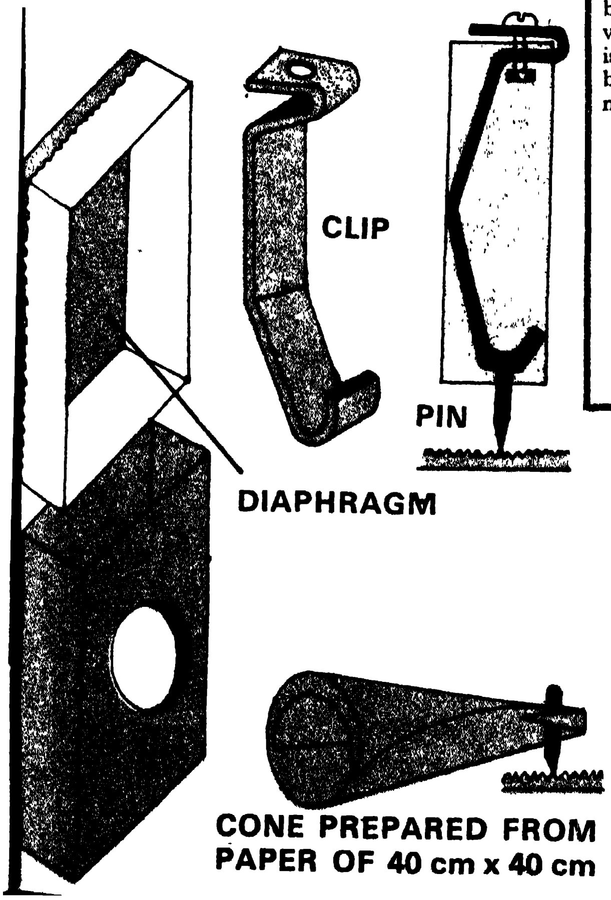
All vibrating air instruments have some means of varying the length of the air column. In organs, it is the length of the pipes. Bugles and horns have coiled tubes and trombones have a slide to vary the length of the air column. Though clarinets and saxophones have a reed to start the air vibrating, the note they produce depends on the length of the column of vibrating air.

In fact, the quality of musical sounds depends not on the 'purity' of the sound but rather on the overtones or 'harmonics' that impinge on the main or 'fundamental' notes. If a thin wire is stretched along the top of a box and then plucked, it can be seen vibrating along its entire length (Fig. a). If we touch it lightly at the midpoint it will vibrate in half-lengths and the frequency of vibrations will be doubled (Fig. b). Similarly, it is possible to make the wire vibrate in sections of a third (Fig. c) or a quarter (Fig. d) of its length, producing sound waves with three or four times the original frequency. In each instance, the note sounded is a 'harmonic' of the original or fundamental note.

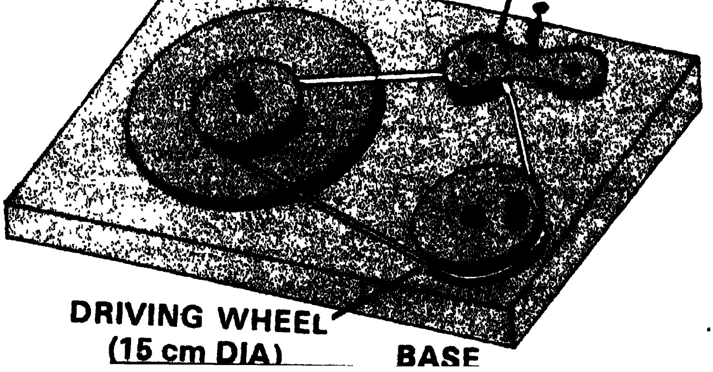


PROBLEM

It is known that some opera singers can actually shatter wine glasses when they sing at a particular high pitch. Why does the glass shatter? And why does it take several seconds before the shattering takes place?



CONE PREPARED FROM PAPER OF 40 cm x 40 cm



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BOOKS

Optimisation techniques

OPTIMIZATION TECHNIQUES FOR CHEMICAL ENGINEERS by Asghar Husain & Kota Gangiah, The MacMillan Company of India Ltd, 1976, 317 pp, Rs. 18

The authors have done a commendable job in presenting an optimal blend of the theoretical and computational aspects of various optimisation techniques of direct interest to chemical engineers. Though the book, in its present form, can serve as a text-book for an advanced undergraduate or post-graduate course, modifications in the introductory chapter and the chapter on constrained optima would enhance its value.

In the introductory chapter, the authors, after defining optimisation and briefly outlining its scope, present not only the basic terminology but also a number of important terms like stationary point, saddle point, Lagrange multiplier, etc. These terms could have been introduced with greater effect at appropriate points in the text. The structure and classification of optimisation problems should have been formally presented.

Unconstrained single variable and multivariable search procedures have been discussed very well in the second and third chapters. The computational aspects of most of the important methods have been clearly explained. The theoretical basis of the variable metric method could have been developed in greater detail at the expense of transformational discrimination. Necessary and sufficient conditions of unconstrained optima should have been outlined at the beginning.

The chapter on constrained optima is presented in too brief a manner. The concepts of Lagrange multipliers and constrained derivatives have been well developed. In the section on inequality constraints, the basis of Penalty Function approach could have been more fully explained with the dual problem. The condenser design problem which follows illustrates only the formulation aspect. The treatment of linear programming is inadequate. The basic properties of LP problems could have been presented in place of the refinery blending problem which emphasises only the formulation aspect. The development of geometric programming is also inadequate. A very useful search procedure like the complex box finds no place in the book. Dynamic programming has been presented skilfully with adequate examples to give the reader a clear idea of the principle of optimality.

The last two chapters are the highlights of the book. The chapter on variational methods presents a concise and lucid exposition of calculus of variations and weak and strong versions of Pontryagin's principle. The computational features as well as the merits and demerits of various methods for solution of TPBV problems have been well illustrated with adequate numerical results. The last chapter on difference method for time domain is significant in the sense that it presents an original contribution of the authors on dynamic optimisation of free terminal time problem. The basis of the method and its computational aspects have been clearly brought out with numerous examples.

K. P. MADHAVAN

[Dr. Madhavan is Assistant Professor in the Department of Chemical Engineering, Indian Institute of Technology, Bombay.]

Breaking the Brahminical barrier?

THE PENGUIN DICTIONARY OF PHYSICS, edited by Valerie H. Pitt, Penguin Books, England, 1977, 428 pp, £2 (Rs. 32)

In these days of pocket calculators, microwave ovens, and satellite television, an increasing quantum of technical jargon elbows its way into the consciousness of modern man. There it sits, familiar, but for the most part impenetrable, like one's neighbours in a city apartment complex.

For readers of science magazines, the problem is more acute since much of modern science is communicated in Brahminical terminology carefully selected for its opacity and proof against leakage outside the caste. Recent trends in modern physics to adopt the lucrative nomenclature of Madison Avenue have not improved the situation — the "charm" of an elementary particle is no more comprehensible to the intelligent layman than its "isotopic spin". The language dictionaries do not usually carry explanations of words like "metal oxide semiconductors" — and this is where a technical dictionary should come in to fill the gap.

A technical dictionary should be reasonably *complete*, and it should be *comprehensible* to its intended audience. How well does the *Penguin Dictionary of Physics* fulfil these criteria? I tested the first by choosing at random 12 words from my physics vocabulary and looking them up. The dictionary carried the meanings of eight of these, including technical terms like Zener diodes, and Schwarzschild radius, but it missed out on important concepts like that of a physical 'state', a 'boundary value problem' and even with 'amorphous semiconductor'.

As for the second criterion, according to the preface, the book is intended for an audience of "students and teachers of physics, doctors, scientists, technologists. . . ." Is it likely to be very useful to the average reader of a magazine like SCIENCE TODAY? I don't think so. Most of the explanations are given in a language as technical as the words it seeks to explain. The only audience that it is likely to serve well is one which is already quite familiar with the subjects, but may have forgotten some details — that is, working physicists, etc.

Booksellers inform us that it is customary to price a book keeping in mind the expected rate of inflation in the period subsequent to its issue. At £2, the publishers of this paperback don't seem to have much faith in the future of the British economy.

VIVEK MONTEIRO

On Group Theory

ELEMENTS OF GROUP THEORY FOR PHYSICISTS by A. W. Joshi (2nd edition), Wiley Eastern Limited, New Delhi, 1977, xiii+324 pp, Rs. 45

The book, written at the MSc degree level of Indian universities, was first published in 1973. That a second edition has been brought out within four years speaks highly of the book. I found the book very good; it is eminently suited to the requirements of Indian students. The major feature that recommends this book, compared to most Western books on this subject, is its explicitness — this should be seen in the context that most students often have to study on their own.

(Contd. on p. 61)

QUESTION & ANSWER

What is a 'neutron bomb'?

A recent news item that had created a lot of stir was about the test conducted in the USA of a new nuclear warhead designed to kill living beings with intense radiation while causing a minimum of blast damage to buildings and equipment. This warhead, which could be placed on missiles, has been called by some as the 'neutron bomb'. What makes it different from the existing nuclear warheads?

The device is likely to consist of an intense source of neutrons generated by a triggered nuclear reaction of a kind which is already well-known in physics. The secret, probably, lies in the technique of initiating a proper nuclear reaction in which high energy neutrons are generated. Let us first examine a few of the most important neutron-generating reactions.

One of the most important present-day neutron sources is the well-known fission reaction. When the nucleus of one of the heaviest elements undergoes fission, it splits up into two smaller nuclei and the nuclear reaction energy is shared between the two fragments in the form of kinetic energy and they begin to move apart. These nuclei, in addition to their kinetic energy, have large excitation energy. They lose their *excitation energy* by emission of *neutrons* and gamma rays of various energies. The unstable nuclear fragments undergo radioactive decay in which beta particles, neutrinos, X-rays and gamma rays are emitted. The energies of these by-products are not fixed but can vary over a range called the energy spectrum of the reaction. For example, a ^{235}U nucleus, if it captures a neutron, will undergo fission. Among the by-products of this fission reaction will be found, on the average, between two to three neutrons. The average energy of these neutrons is about 1·5 MeV. In the chain-reacting-pile (nuclear fission reactor), these fast neutrons are slowed down (moderated) by elastic collisions with light nuclei and inelastic collisions with heavy nuclei. Slowing down the neutrons enhances the probability that they will be captured by other uranium nuclei, which will then undergo fission, and so on.

In the fission of a ^{235}U nucleus, only a small part of the energy released is carried by the neutrons — only about 5 MeV out of nearly 200 MeV energy released. Of the remaining 195 MeV, nearly 165 MeV is taken up in the kinetic energy of the heavy fission fragments (which is then lost in the surrounding medium causing blast and heat), about 10 MeV in the form of gamma rays, 8 MeV in the electrons released and 12 MeV in the neutrinos. Therefore, in an uncontrolled nuclear fission chain reaction, namely, the nuclear explosion, nearly 85 per cent of the energy released contributes to the blast and heat that damage the surroundings and the remaining 15 per cent appears as fallout radiation, gamma rays and neutrons which are harmful to biological species. The distribution of energy is shown pictorially in Fig. 1a.

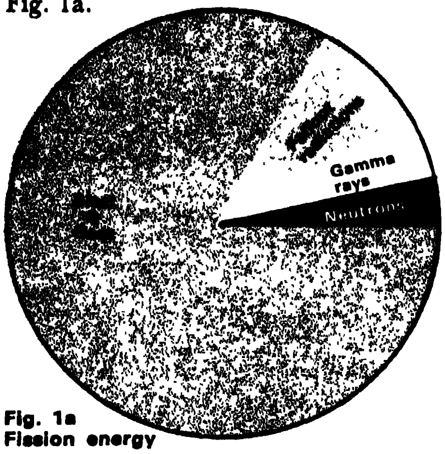

Fig. 1a
Fission energy

The most powerful and versatile sources of neutrons available today are obtained by accelerating charged particles and bombarding a suitable target. Consider the fusion reaction induced by the deuteron (heavy hydrogen) on deuteron which is represented as $^{2}_{1}\text{H} + ^{2}_{1}\text{H} \rightarrow ^{3}_{2}\text{He} + \text{n}$ + energy (3·265 MeV). This reaction releases energy and has appreciable neutron yields for low bombarding energies ($\lesssim$ 100 keV). This energy is comparable to very high temperature plasma sources used for thermonuclear reactions in which neutron sources in the range of 10^{14} cm^{-2} sec^{-1} (per square cm per second) are obtained.

Consider the second most important fusion reaction induced by the deuteron on the tritium (heavier hydrogen) nucleus, symbolically represented as $^{2}_{1}\text{H} + ^{3}_{1}\text{H} \rightarrow ^{4}_{2}\text{He} + \text{n}$ + energy (+ 17·6 MeV). This reaction is highly energetic, releasing about 17·6 MeV per nuclear fusion. Neutrons of about 14 MeV energy are generated by the low energy deuterons ($\sim$ 100 keV) bombarding the triton target atoms. Since there is a resonance in the reaction yield at $E_d = 100$ keV, the neutron yield will be large enough at this energy. Therefore, if one can create a plasma containing both heavy hydrogen ($^{2}_{1}\text{H} = \text{D}$) and heavier hydrogen ($\equiv {}^{3}_{1}\text{H} \equiv \text{T}$) at the thermonuclear reaction temperature, fusion will occur, and high energy (14 MeV) neutrons can be generated.

Note that most of the energy released in thermonuclear fusion reactions described above is in the kinetic energy of the neutrons (Fig. 1b). Thus, fusion reactions are neutron-rich while fission reactions are energy-rich.

In this context, the announcement of a break-through in the production of neutron bomb means that it has been possible to produce a neutron-rich explosion minimising the blast energy that is associated with the bomb. In the ordinary fusion bomb — for example, a hydrogen bomb — the trigger is usually a fission device, which itself produces enormous blast energy in addition to energy produced in the fusion reactions. In a neutron bomb, obviously, there does not seem to be a fission trigger, thus minimising the blast energy produced and enhancing the number of neutrons produced per unit of explosive energy. It is conceivable such a device could have been built on the basis of very secret technological developments in the area of high-density pulsed plasmas. It is not yet clear what the technical method is.

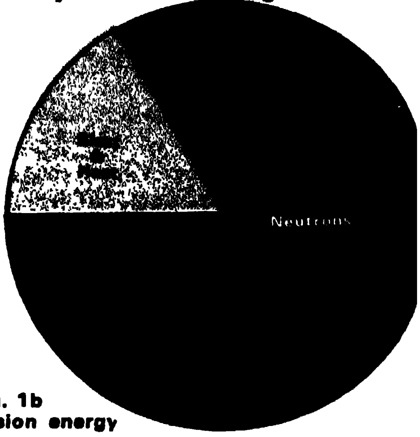

Fig. 1b
Fusion energy

The description of the neutron bomb as being similar to a tactical weapon seems to indicate that the yield of these devices must be smaller than the smallest atomic bomb (namely, in the 10 kiloton range), and would depend upon the neutron radiation for its destructive properties. The biological effects of fast neutrons are generally known for they cause intense damage in the biological systems through the interactions with the hydrogen atoms of organic matter (high-energy proton recoil).

The yield of fast neutrons in such a device could be in the range of 10^{18} cm^{-2} sec^{-1} compared to laboratory neutron sources in the range of 10^{14} as described earlier. It is indeed unfortunate that technology has developed such an intense source of neutron radiation that can be projected through rockets and missiles. This gives a new dimension to the subject of nuclear proliferation for it may well mean that there is no need for uranium or plutonium for producing nuclear lethal weapons.

As far as pure science goes, the ability to produce fusion neutrons in such large quantities is an interesting development and could lead to several basic research applications such as production of new isotopes by multiple neutron capture processes and conversion of fertile material into fissile material, for example, ^{238}U into ^{239}U, or thorium into ^{233}U.

One special characteristic of a neutron bomb would be that it could avoid detection at long distances through the standard seismic methods for the radiation could not be detected at great distances, and since the blast energy is minimal, it will not produce characteristic seismic signals when exploded underground. It is possible that testing of such devices has gone on for several years even as the superpowers were negotiating test-ban treaties and it is only now that a formal announcement has been made. This shows that the realities in the development of more lethal weapons are far ahead of what is talked and negotiated in these meetings.

M. C. JOSHI

[Dr. Joshi is Professor and Head of the Department of Physics, University of Bombay.]

Round-up of Research *(Contd. from p. 31)*

In their experiments, reported in *Science* (**196,** 877, 20 May 1977), they identified in the fossil leaves, by the technique of paper chromatography, the flavonol kaemferol and dihydrokaempferol, the flavanonol form of kaempferol.

They state that their results suggest that the flavonoids from the fossil *Z. oregoniana* represent original unaltered flavonoids. According to them, the rapid burial of the leaves under volcanic ash and the apparent lack of elevated temperatures in their subsequent geological history explain the preservation of the organic compounds. The material from the Succor Creek flora, in fact, represents the first case of the preservation of flavonoid compounds in comparably aged rock strata.

K. A. NEELAKANTAN

LL US WHY . . .

. . . peoples' voices sound different?

Basically, for the same reason that soldiers are ordered, while crossing a bridge, to break their marching rhythm.

Like a pendulum, a bridge has its own natural frequency of oscillation. This is just the frequency at which it oscillates when it swings freely. And since a pendulum can be made to swing wildly by "pushing and pulling" it in time with its natural frequency, so, legend has it, bridges are apt to collapse if the rhythm of the soldiers' marching matches that of the bridge. Putting it more generally, any oscillating system can be made to oscillate strongly by subjecting it to external forces which oscillate with the same period. Such "sympathetic vibrations", called resonances, are responsible for approximately half the interesting phenomena in physics, including those of radio, television, musical instruments, photosynthesis, sight and hearing, elementary particles, atomic spectra, and the human voice.

The most interesting and useful property of resonating systems is that they respond more or less selectively to external periodic forces. A system with a natural frequency of 200 cycles per second (cps) will respond strongly to an external force with the same, or nearly the same, frequency. But it would not respond sympathetically if the force frequency was, say, 250 cps.

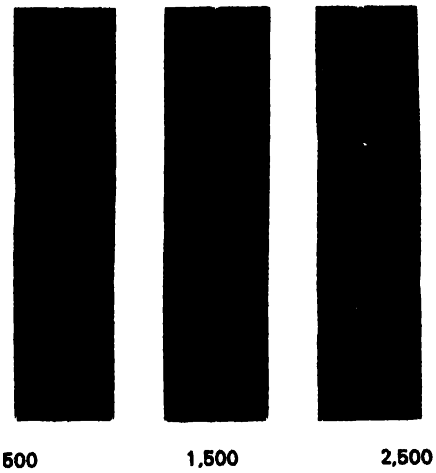

Fig. 1

A system may have several natural frequencies. For instance a taut string has an infinite number of resonant frequencies with relative ratios 1 : 2 : 3 . . . . etc, so that if the lowest frequency at which it resonates is 200 cps, then it will also resonate at 400 cps, 600 cps, etc. Similarly, an air column in a tube which is closed at one end and open at the other, has many resonant frequencies, but these are in the ratio 1 : 3 : 5 : 7, etc (see Fig. 1). What does all this have to do with the human voice?

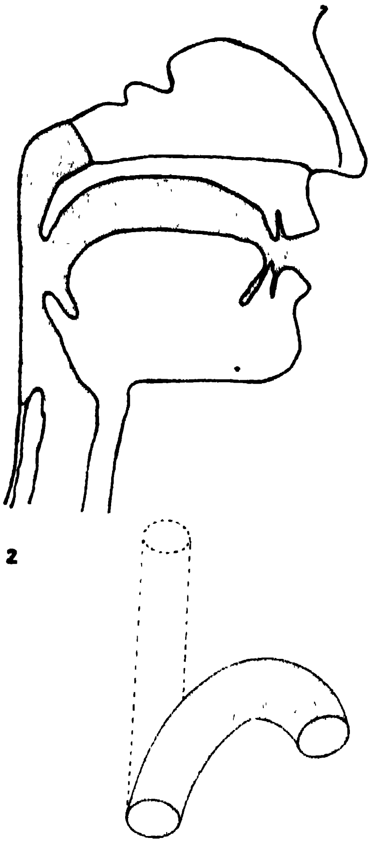

Fig. 2

After considerable mental simplification (see Fig. 2), the human vocal tract may be likened to a tube which is closed at one end (at the glottis) and open at the other (at the lips of the mouth). In an average man, this tube is around 17 cm long. A half-open tube of this length (actually the air column inside it) should have resonant frequencies of 500 cps, 1,500 cps, 2,500 cps and so on.

Now what happens when we speak? Air from the lungs is forced past the vocal chords (glottis) which vibrate like the reed of a clarinet sending into the vocal tract an output consisting of a jumble of frequencies. But here the *selective response* of the tract comes into play — only those frequencies near 500, 1,500 and 2,500 cps are 'picked up', so that the sound output near the mouth (that is, the "voice") consists primarily of just these frequencies, plus of course some residual frequencies.

What about the *shape* of the vocal tract? How does it affect the sound output? It turns out that this determines the loudness at which each individual natural frequency is excited. Thus, the natural frequencies themselves depend mainly (but not solely) on the *length* of the vocal tract, but the relative mix of these frequencies in the final output depends mainly on how the *shape* of the tract is varied.

Peoples' voices sound different because of the different 'resonant properties' of their voice tubes. Except for loudness, the lungs don't have much to do with the problem. What we hear depends on the length of speaker's voice tube, and how he uses his throat muscles.

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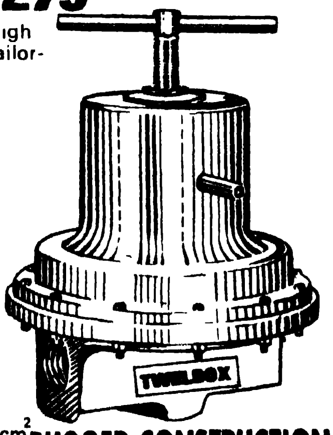

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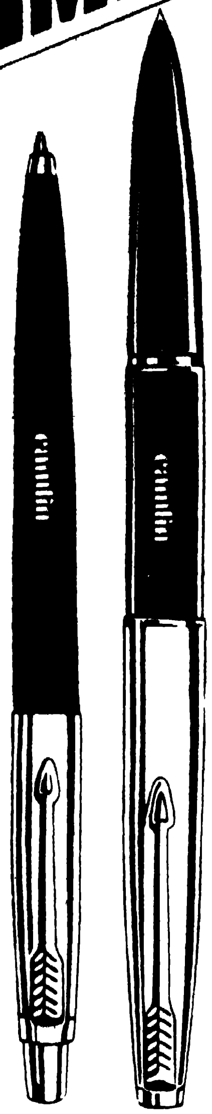

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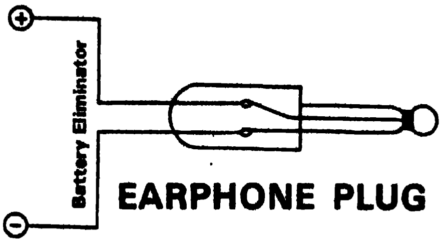
BATTERY ELIMINATOR

It is not economical to use transistor radios, transistorised cassette players, or any other electronic gadget with dry batteries where mains supply connections are easily available. You can build yourself a mains-operated battery eliminator which can supply the appropriate DC supply to operate the devices.

As you know, the mains supply available almost throughout the country is 230V AC, 50 Hertz. The transistorised devices, depending upon their type, work either on 3, 6, 9 or 12 V DC supply and their current requirement is normally within 250 mA. Transistor radios normally work on 3 or 6 V DC batteries and their current requirement is within 100 mA. The cassette recorder/players work on 6 or 9 V DC batteries and their current requirement is within 200 mA. With the circuit given below, you can select any voltage, 3, 6, 9 or 12 V DC with the selector switch and the maximum current the circuit can provide is 250 mA. However, if you require any other DC voltage source, up to 90 V DC and 250 mA, you can design your own battery eliminator unit, using the basic circuit and the data given below.

The battery eliminator, basically, consists of three parts: a step-down transformer, bridge rectifier and filter circuit. The step-down transformer provides across its secondary, the necessary low voltage AC supply to the bridge rectifier. The bridge rectifier converts the AC voltage to DC. Though this voltage provided by the rectifier is DC, that is, unidirectional, it has still a fluctuating nature. The capacitor across the output is called filter capacitor, which acts like a fly wheel and provides a steady DC output. The resistor across the capacitor is called bleeder resistor.



You might wonder why the DC output voltage available is slightly more than the AC voltage provided by the transformer secondary. This is because the AC voltages are always specified as the R.M.S. value of its sine wave behaviour, whereas the rectified output across the filter capacitor has the tendency to attain the peak value. The theoretical equation of the DC (V DC) voltage under no load condition, across the capacitor, is given below.

$$V\,DC = V\,AC \times \sqrt{2} - 1{\cdot}2\ V$$

where 1·2 V is the drop across the silicon bridge rectifier.

The value of V DC drops slightly, depending upon the current drawn from the battery eliminator.

For all practical applications, where V DC ≫ 1·2 V, under normal loading condition

$$V\,DC = 1{\cdot}2 \times V\,AC\ \text{(approx.)}.$$

By fixing the earphone socket on the cabinet of the transistor radio and the plug to the output terminals of the battery eliminator, one can provide a very handy arrangement which disconnects the internal dry batteries of the transistor radio or cassette player when the plug is inserted inside the socket; the connections are brought into play when the plug is removed. With the battery eliminator, the transistor radio or cassette player can thus be used with dry batteries, and inside the house, by simply inserting the plug into the socket.

You will need:

Semiconductors: silicon rectifiers, BY 126, 4 nos.

Transformer (made to order): Pri: 230 V A.C.; Sec: 0–3·5–6–8·5–11 V A.C. @ 250 mA, 1 no.

Capacitor (electrolytic): 1000 mfd 16 V, 1 no.

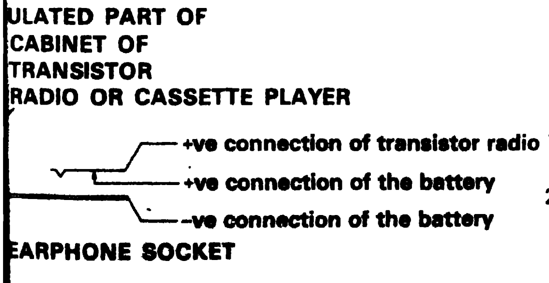
Resistor: 1K 1/2 watt, 1 no.

Switches: On/Off switch, 1 no.; 1 pole, 4 way, 1 no.

Fuse: 250 mA with fuse holder, 1 no.

Misc.: neon lamp (230 v type); earphone plug socket; suitable enclosure; terminals; lug strip or group board; wires, solder, screws, knob, mains plug, etc.

DC OUTPUT REQUIREMENT V DC VOLTS	mA (MAX.)	TRANSFORMER (Pri = 230 V AC) SECONDARY V AC		CAPACITOR C		BLEEDER RESISTOR R
22·5 V	50 mA	18·75 V	50 mA	250 MFD	25 V DC	4·7 K ½ W
	100 mA		100 mA	500 MFD		
	250 mA		250 mA	1000 MFD		
45 V	50 mA	37·5 V	50 mA	250 MFD	50 V DC	10 K ½ W
	100 mA		100 mA	500 MFD		
	250 mA		250 mA	1000 MFD		
90 V	50 mA	75 V	50 mA	250 MFD	100 V DC	22 K 1 W
	100 mA		100 mA	500 MFD		
	250 mA		250 mA	1000 MFD		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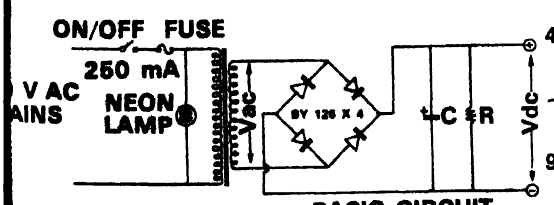
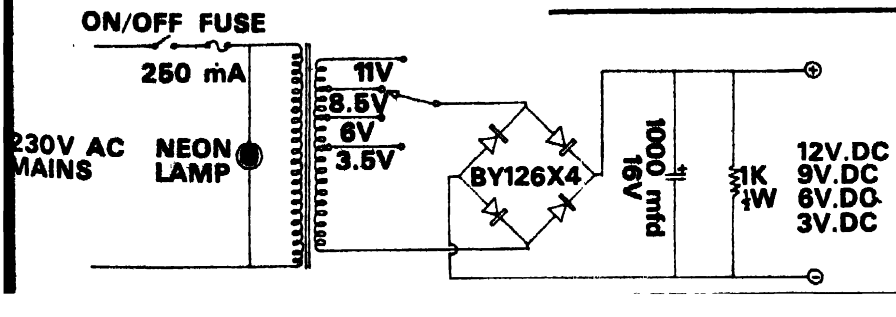
TRANSISTOR
RADIO OR CASSETTE PLAYER
+ve connection of transistor radio
+ve connection of the battery
–ve connection of the battery
EARPHONE SOCKET



BASIC CIRCUIT



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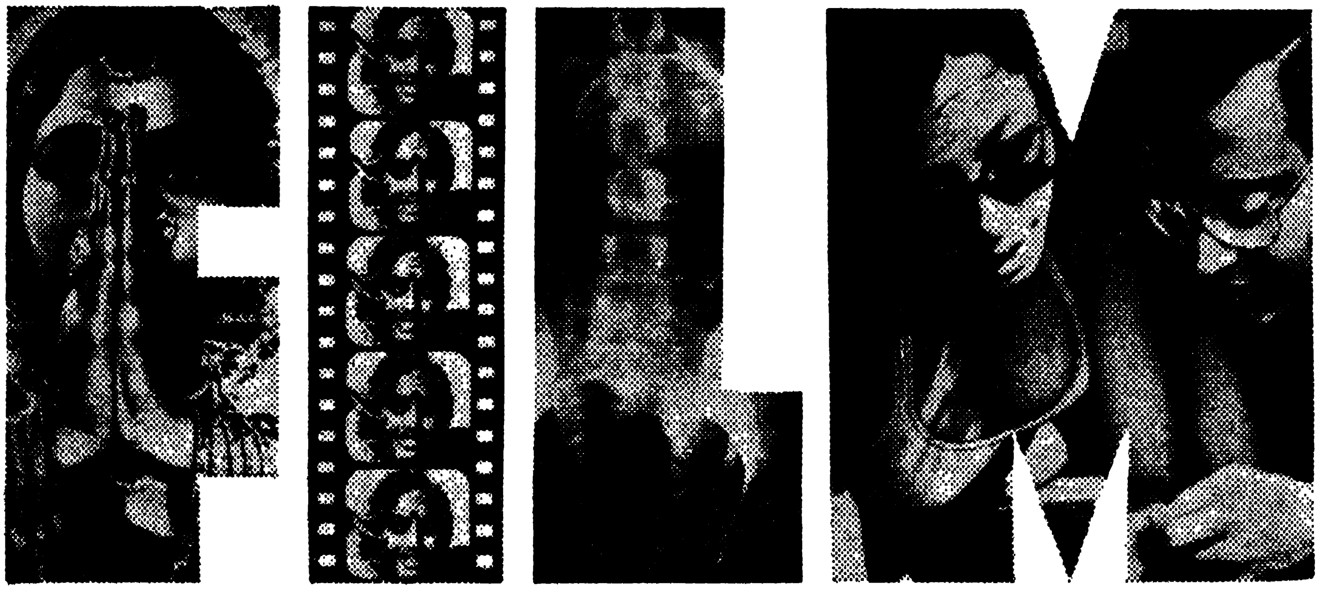

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BRAIN TEASERS

FOUR AILMENTS: If 70 per cent of the population of a certain town have stomach trouble, 75 per cent have cataract, 80 per cent have liver ailment, and 85 per cent have a touch of catarrh, what per cent, at the least, are plagued with all four ailments?

K. S. S. NARAYANAN

THREE FRIENDS: Each of three friends, Arun, Binod and Charan, practises a profession and a hobby. Among them, they have six professions and hobbies. The following facts are known about them:

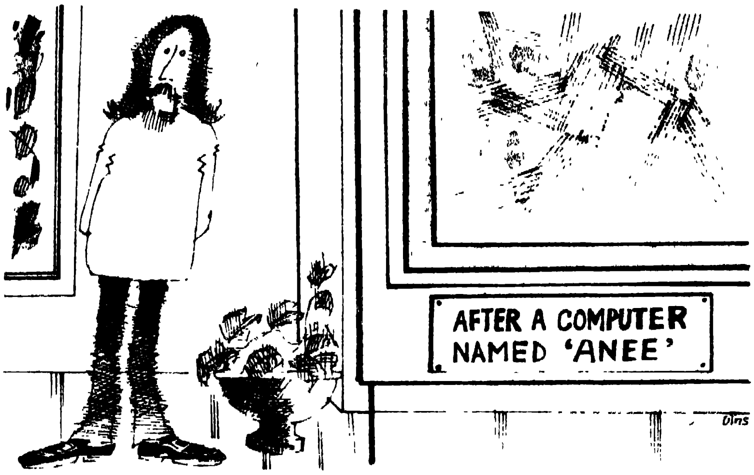
1. The teacher lent a rare book to the banker.
2. One day Charan gave a lift to both Binod and the banker in his car.
3. Both the social worker and the philanthropist were entertained by Arun.
4. The grocer obliges the banker by depositing his savings in his bank.
5. Binod and the philanthropist are the office bearers of a cultural organisation.
6. The grocer praises the social worker for his selfless service.
7. One of them is a cricketer. Can you find out who is who?

V. A. SHENAI

(Solutions next month.)

[illegible]

[illegible]	A	[illegible]	C	[illegible]	[illegible]
Principal	11✓	[illegible]	1X	2X	[illegible]
Vice-principal	12X	15✓	3X	4X	[illegible]
Student Counsellor	13X	17X	21X	23✓	[illegible]
Hostel Warden	14X	18X	20✓	8X	7X
Nil	[illegible]	[illegible]	22X	24X	25✓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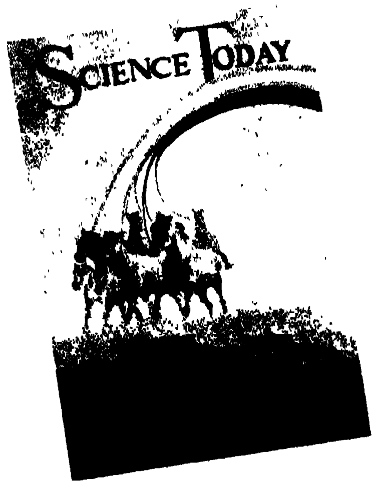

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HIGHLIGHTS OF THE NEXT ISSUE

- WHAT MAKES A RAINBOW?
- THE MANY USES OF COMPOSITES
- LET'S GET TO KNOW OUR TREES
- HOW GOOD ARE OUR ELECTRICAL APPLIANCES?
- 'SPEAKING' THROUGH THE EYES

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AWARDS & APPOINTMENTS

Lady Tata Memorial Awards

Five foreign scientists have been awarded the Lady Tata Memorial International awards for 1977-78 for studies in the diseases of the blood, with special reference to leukaemias. The awards are made annually by the Lady Tata Memorial Trust.

The awardees are: Dr. R. Bastos, of Brazil, Rs. 56,000 (£3,500) for the study of molecular regulation of erythroid differentiation in normal and leukaemic cells, at the Weizmann Institute, Rehovot, Israel; Dr. P. Mignatti, of Italy, Rs. 24,000 (£1,500) for the study of transformation-enhancing factors produced by transformed and malignant cells, at Pavia, Italy; Dr. Z. Ravid, of Israel, Rs. 56,000 (£3,500) for an attempt to isolate and establish in culture the 'premalignant' and malignant cells of Mediterranean intestinal lymphoma, at Hebrew University, Hadassah Medical School, Jerusalem; Dr. H. T. Jacobs, of Britain, Rs. 24,000 (£1,500) for the study of controls on transcription and RNA processing in normal and neoplastic cells, at the Beatson Institute for Cancer Research, Glasgow; Dr. J. Grosslerner, of France, Rs. 56,000 (£3,500) for the study of phenotype mixing of simian foamy virus and baboon (*Papio cynocephalus*) type C endogenous virus at the Imperial Cancer Research Laboratories, Lincoln's Inn Fields, London.

Besides, the Trust has also given eight senior and eight junior scholarships for scientific studies in India, having a "bearing on the alleviation of human suffering from disease".

NEERI Director

Dr. B. B. Sundaresan has taken over as Director of the National Environmental Engineering Research Institute, Nagpur. Dr. Sundaresan has till now been Professor-in-charge of post-graduate studies and research and also Dean of the College of Engineering, Guindy, Madras, in the Department of Technical Education, Tamil Nadu. Dr. Sundaresan had developed and patented a "dry process for control of nitrogen emissions from nitric acid manufacture", while he was doing his post-doctoral research in air pollution control systems at the University of Florida, USA.

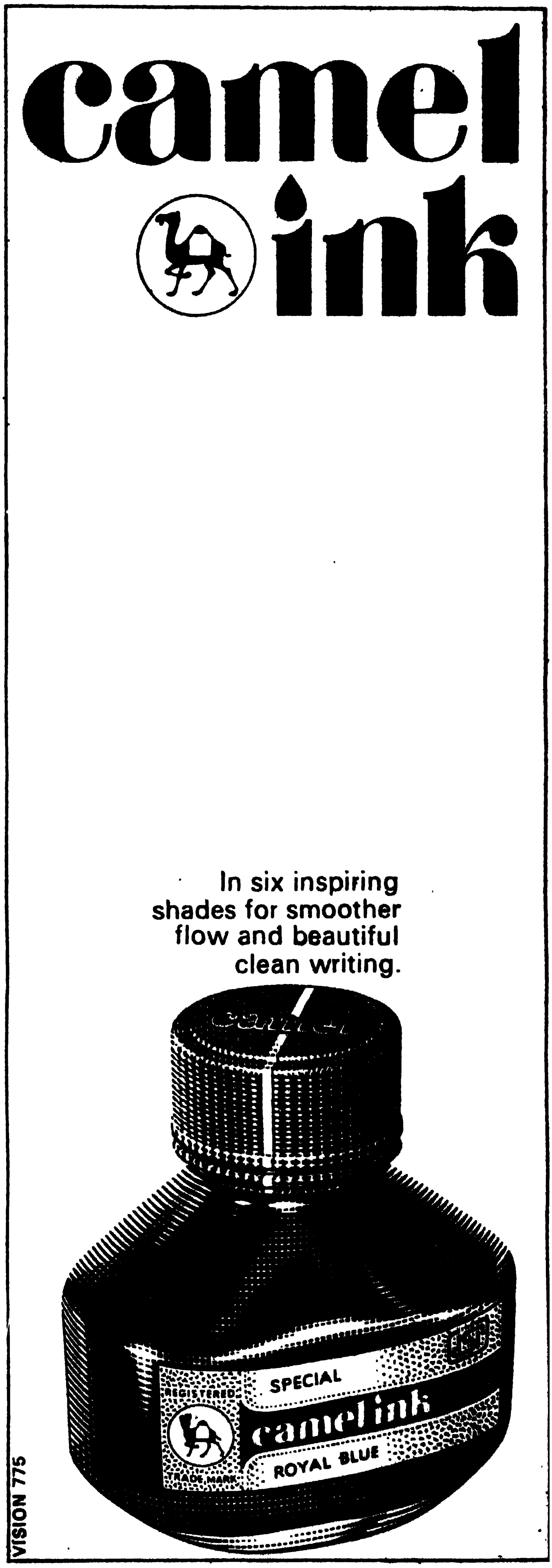
BOOKS *(Contd. from p. 53)*

The book opens in the traditional fashion with a discussion on abstract group theory and then proceeds to the representation theory for both finite and continuous groups. With the basic mathematical equipment developed, it then proceeds to apply it to quantum mechanics, incorporating various areas of atomic physics, crystallography and molecular symmetries, ending with a chapter on the use of group theory in solid state physics.

There can be little dispute about the basic material covered — it is by now standard. One would have liked to see a more detailed discussion of atomic, molecular and nuclear physics — a simplified version of treatments in the standard books of Tinkham or Heine. The book would then have been a great help in providing the student community with an introduction to applications of group theory in the non-relativistic domain. Another topic worth discussing would be the more elementary aspects of the representation theory of symmetric groups very useful in the discussion of representations of other groups.

A. A. RANGWALA

[Dr. Rangwala is with the Physics Department, Bombay University.]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Your children are under constant attack!

It is scientifically established that boiling water is insufficient

It's now an established fact that boiling alone is no longer safe. Boiling only kills germs, **but not spores.** You need something that rids you of both. For, spores are the resting stage of bacteria present in water. And even a temperature of 100 degrees C (the boiling point of water) has no real effect on them. A few hours after boiling, they are back in action again, contaminating the freshly boiled water.

Beware of the Matka!

Ask any scientist friend. He'll tell you. Even boiled water stored in matkas is dangerous. For matkas breed germs by the million, in their millions of earthenware pores. Why, even crystal clear water examined under the microscope shows bacteria which cause cholera, typhoid, dysentery, jaundice, gastroenteritis and other terrible diseases.

There must be a solution!

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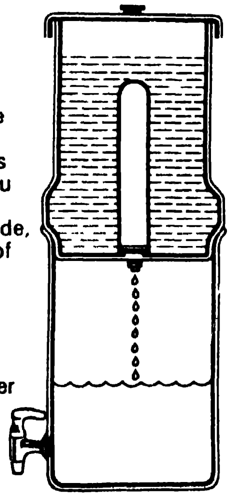

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The secret lies in the Puritas Candle, the first of its kind in India. All Puritas Candles are laboratory tested and certified by leading municipal authorities. These candles are made of a very special kind of earth called 'Kieselguhr' which is so precisely porous, it makes the ideal filtering material. In fact, **it filters out all germs and spores, providing you with 100% pure drinking water** in the lower chamber.

Where is the proof that Puritas gives 100% pure water?

We have proof. You are most welcome to come over to any of our offices in India and check photostat copies of actual laboratory test reports. You can also check the originals at our Head Office in Bombay—reports that prove without doubt that the Puritas Water Filter removes bacteria totally. Assuring you of water that is 100% free of germs and spores. 100% safe for your growing children and for you.

Caution

Buy only genuine Puritas Water Filters for your own safety. Check the Puritas label on the upper chamber. See that the Puritas name and Registration No. 196501 are on the metal base of the candle.

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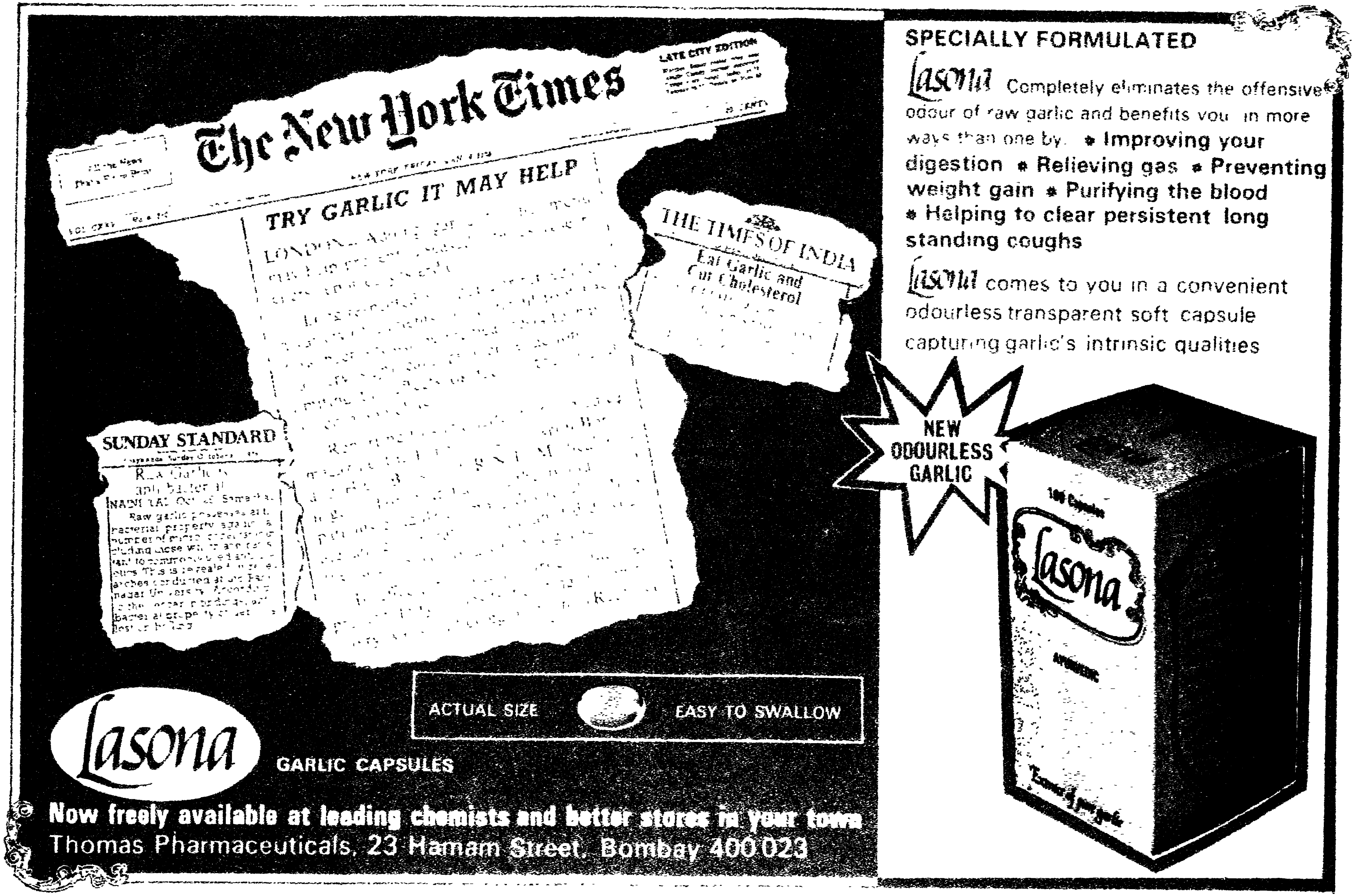

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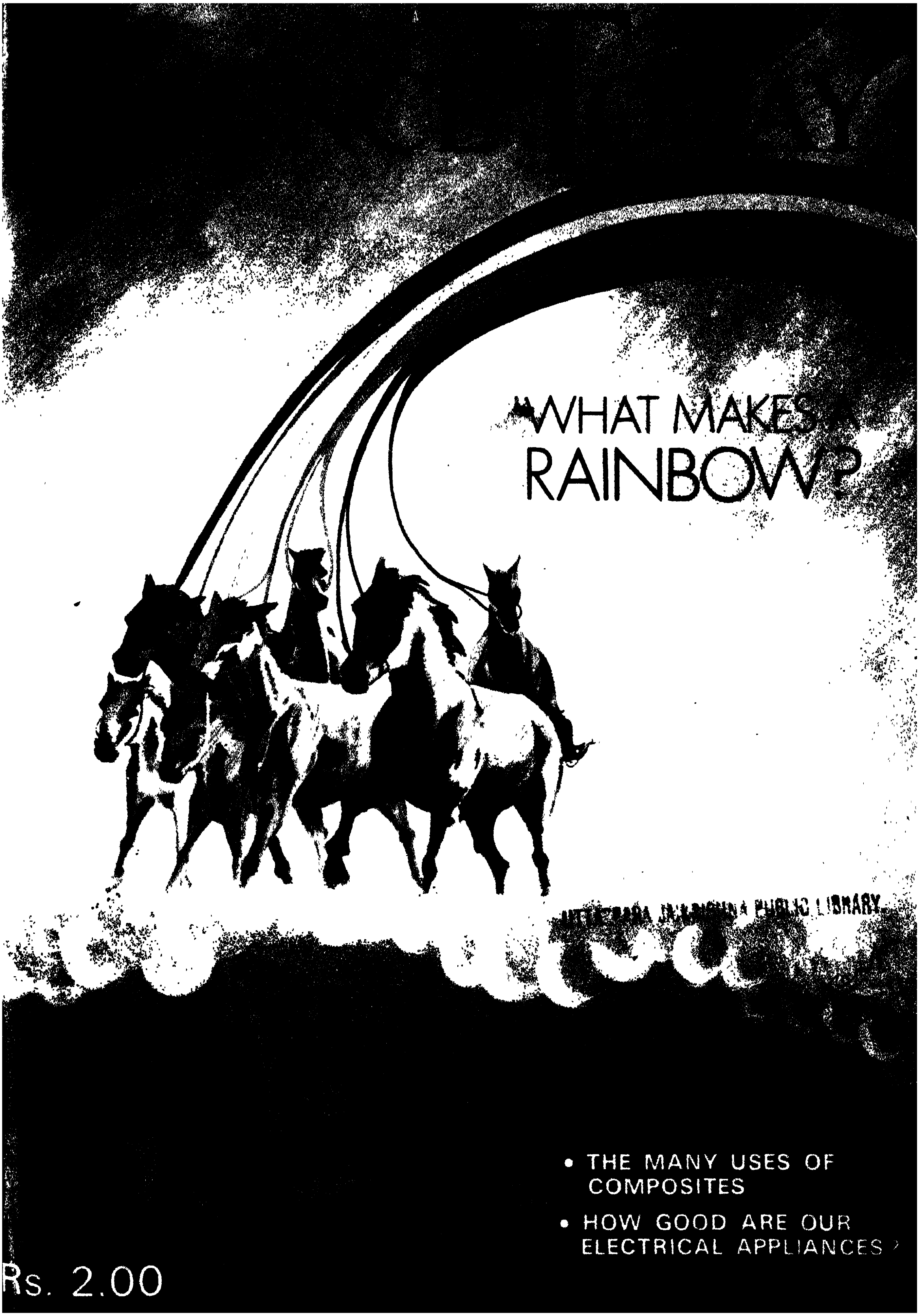

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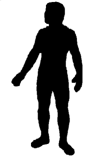

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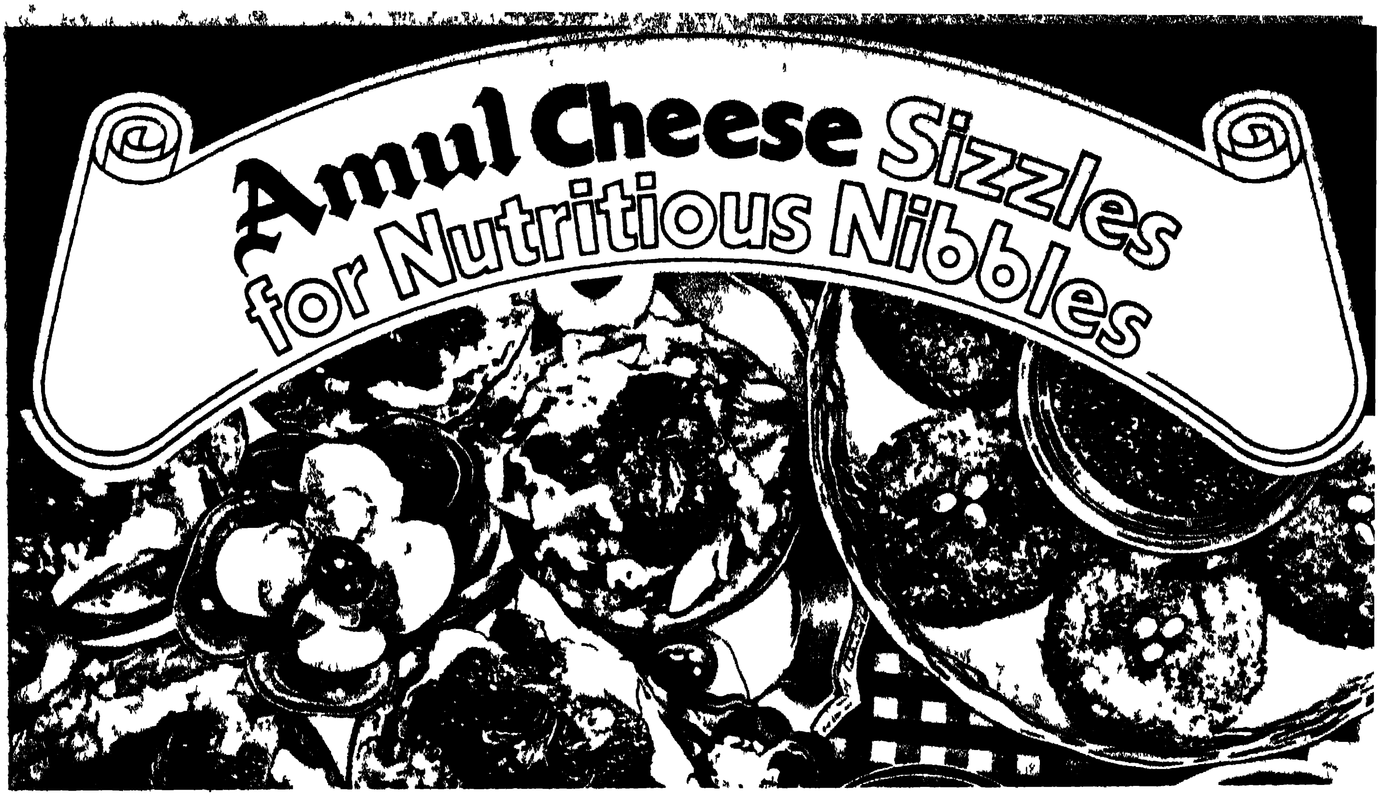

Amul Cheese Wedges

1 well-beaten egg • ½ cup milk
1½ cups packaged crushed salty
  biscuit mix
1 cup grated Amul Cheese
2 tsp poppy seeds
2 tbsp melted butter

Combine egg and milk, add to biscuit mix and stir only till dry ingredients are just moistened Add half the Cheese Spread this dough in greased 21 cms x 4 cms deep, round baking dish Sprinkle on remaining Cheese and poppy seeds, then melted butter, over all Bake (150°C) for about 20 minutes Cut in wedges and serve hot

Amul Cheese Kachauris

½—1 kg mashed potatoes
1 tbsp til ground • 1½ tsp
  khus-khus
½ tbsp chironji nuts • Breadcrumbs
A stick of cinnamon
1 tbsp lime juice
1 clove powdered
1 tsp green chilli paste
1 tbsp sugar • Salt
Ginger, small piece finely chopped
Coriander leaves, chopped
3 tbsp grated coconut
200 gm Amul Cheese Powder

Knead all ingredients well—except Cheese Divide dough into equal portions and form into large balls Keep aside Knead Cheese Powder stuff into potato balls Roll balls in breadcrumbs and fry till golden brown

Amul Cheese Quick Pizza

4 buns or rolls
2 onions sliced
4 button mushrooms, sliced
2 tomatoes sliced
1 cup grated Amul Cheese
1 cup chicken boiled and
  shredded
½ cup oil • 1 tsp salt • 1 tsp
  pepper
1 extra onion • 4 tbsp tomato
  sauce
1 clove garlic, chopped
2 tbsp mint leaves, chopped

Slice buns or rolls into halves Keep tops aside Brush surface of bottom halves with oil Heat oil, fry onion, garlic, mushrooms and chicken for four to five minutes and remove Mix Cheese and tomato sauce Place bread on a baking tray Sprinkle salt and pepper on each piece Spread chicken mixture evenly on top of each slice and cover with Cheese mixture Garnish with onion rings and chopped mint leaves Bake in an oven (95°C) till Cheese mixture sets Serve hot

Amul Cheese and Egg Cakes

4 eggs • 45 gm flour
1 tbsp grated onion
90 gm diced Amul Cheese
(Chiplets) • Salt • Pepper
Butter to fry

Beat eggs, add onion, flour and Cheese, season to taste with salt and pepper Mix well Taking a tablespoon of mixture at a time fry in butter, turning to brown cakes on both sides Serve at once

Amul Cheese Stuffed Tomatoes

4 large tomatoes • 3 eggs
25 gm butter
4 tbsp grated Amul Cheese
Chopped parsley or coriander
Green chillies, chopped
Salt • Pepper

Cut a slice off top of tomatoes and scoop out pulp Beat eggs and season with salt and pepper Heat butter add beaten eggs and almost all the grated Cheese Scramble lightly Add tomato pulp Fill into tomato cases Garnish with chopped parsley or coriander and chillies Sprinkle with remaining grated Cheese. Place under grill or in oven till Cheese melts

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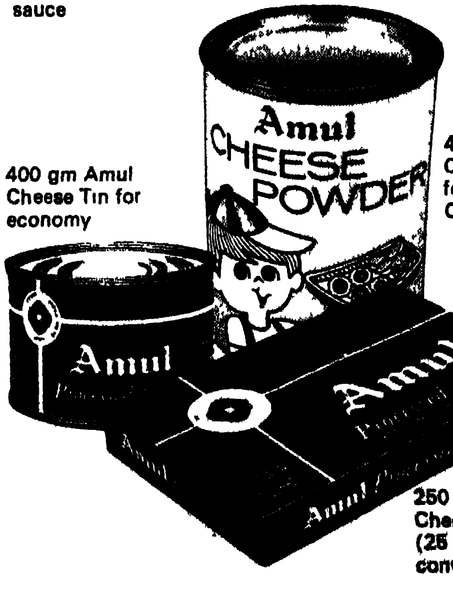

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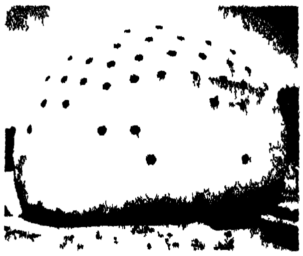

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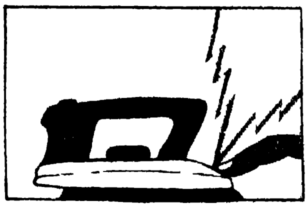

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WORDS = WEALTH

Let's take a look at how "Words" control your life:

Getting the right jobs:

Why is it that most job applications are rejected? It's because when writing an application—most people forget to present themselves "In the right selling words" The right "words" were missing that might have brought the interview.

Winning over others:

Now suppose you've somehow managed to get an interview—The panel asked you questions—and you got stuck for the "right words" to answer—and that knocked your confidence out You wished you kept saying the "right words" to make the correct impression, to show your knowledge, your abilities, your potential!

Succeeding in every job:

You have to communicate either orally or through memos/letters to bosses or subordinates—suppliers or buyers The "right words" used in talking to subordinates could get them to work better, motivate them, helps them to respect you—help you do better The "right words" used in communicating to your bosses—could get them to realise how much you know—how well, you're making the "right" analysis (again in words), the right decisions—and they'll believe you're the right one to be promoted

The "wrong" words could kill your career!!It's so true! The "right" words used in an agreement with a buyer customer—could make a great sale or lifelong customers—"Misunderstanding" of the words used in the agreement could mean customer loss, dissatisfaction and sometimes litigation—yet how often does one use the right words?

You Communicate With Words,

yet, how often were you stuck for "The Right Words?"

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Isn't the way people describe you in "words", the way you describe yourself in "words"?—the key to identify the way you think, the way you work, the way you can show your true self?

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Consider the overworked word 'big' and see what substitutions you can think of on the list·

	Here are suggestions
A big house	A huge house
A big war	A gigantic war
A big cave	A mammoth cave
A big status	A colossal statue
A big room	A spacious room

In each case, doesn t the synonym create a sharper, more accurate picture? This is just a sample of how this cause can lend new polish and effectiveness to your everyday expression

"The Right Words? Let me tell you what it has done for me-It's got me the job I really wanted!"

Anil Kullarwar.

AKullarwar

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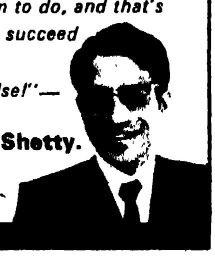

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Your satisfaction with the "Right Words,"

in helping you succeed in life is our main objective—and you can take one word for it, that if you'r not satisfied in every way—we'll refund your money

Remember your future, lies in the "Words" you use use the "Right Words" to build your own wealth!

Pick up a memo,

a letter, an agreement and study it carefully—Yes, it could have been better—using the "right words".

"The difference between the right word and the almost right word is the difference between lightning and the lightning bug".

— MARK TWAIN

HEADSTART-RW-555

New phase in science policy?

It has often been said that the country has not benefited sufficiently by science and technology. It has, in fact, become fashionable to accuse science and the work of scientists. Since science is now being reorganised at all levels and the structure of scientific agencies is being altered, it is in the interest of science that important decisions on science be taken through consultations with a cross-section of the scientific community.

The Indian National Science Academy extends its fullest co-operation and support to the Government in its efforts to eradicate poverty, to improve rural economy as well as to evolve plans for development through science and technology. The President and the Council of the Indian National Science Academy have, therefore, adopted the following resolution.

"The Council of the Indian National Science Academy (INSA) feels concerned by the various statements made in the press, at different conferences and other public platforms that the country has not benefited sufficiently by the ushering in of science and technology since Independence. It is to be said, on the contrary, that the impact of science and technology on Indian industry and agriculture has been such as to put the country in a very special position among the developing nations of the world. Its approach to its problems through science tempered by its ancient wisdom of viewing everything in a humanitarian way has allowed us to develop our technology in such a way as to bring out the genius of its people and be an example to other countries.

It is true that in a situation of a runaway population, the benefits are not visible everywhere, but anyone who wishes to investigate for himself the advances made in agriculture, health, nuclear science, space, metallurgy and so on will be dazzled by all that has been achieved in such a short time and much of it purely by Indian efforts. It is well recognised that it is by the application of modern medicine that the country has been able to increase life expectancy, decrease the incidence of communicable diseases and to rid itself of epidemic diseases such as smallpox and plague.

It has become fashionable to accuse science and the work of scientists for various acts of omission and commission. The failure to have good water supplies in towns and villages, poor quality of roads, unhygienic hospitals, poorly constructed buildings, lack of nutritious food, etc are not due to science, but due to poor management and administration, indecision at political levels and the stronghold of superstitions on our simple folk.

The import of foreign technology begins to look attractive under these conditions, but the real strength of the country lies in its becoming self-reliant in as many aspects as possible. We are not merely a country, but a small continent and have some of the most capable people in the world among our 600 millions. We will never be able to utilise their talents and give them confidence if we run after foreign inputs which, for all the advantages they provide in the beginning, will have an adverse effect on our economy due to the high rate of obsolescence of imported technology. There is no substitute for self-reliance based on indigenous basic and applied research. This is the only way early obsolescence can be avoided. Situations may, however, exist, as with certain well established technologies, where it would admittedly be futile to expend large sums of money in repetitive R & D efforts rather than importing the know-how for appropriate development towards practical ends. On the other hand, we have the talent and resources for taking innovative leads on our own for absorbing imported technologies as well as for competing with contemporary technological advances elsewhere. These should be encouraged.

Lack of proper planning and adequate funding have brought our educational system to a position of stalemate wherein teachers and educators find themselves in the unenviable position of having to train a large number of students in our colleges and universities. This has led not only to unhealthy proliferation of higher education which has no relevance to the needs of the country but also to an increase in the number of educated unemployed. Vocational training at schools is just a paper plan and polytechnics as well as industrial training institutes as planned today have a long way to go before they are useful to the needs of the area. No attempt has been made to improve the social status of a technical worker so that people who wish to become technicians are always made to feel inferior to an administrator. In recent times, there is a feeling that even scientists will be reduced to the position of secondary citizens in matters of decision-making compared to those in administration. We would like to point out that in the advanced countries, professors and other skilled professionals are highly respected in the community similar to what used to be in ancient India. It is not fully recognised, and we should like to emphasise, that good science and technology at the frontiers are required for solving complex problems of rural development and, for this purpose, proper interfaces have to be developed. It has often been stated that scientists must work in villages. Unless specially trained for this purpose, it would be a waste of their aptitude and training. Their views are rarely accepted in the village, especially if they are outsiders.

We understand that science is being reorganised at all levels and the structure of scientific agencies is being altered. It is no doubt necessary that the various commissions and agencies created in the past require reorganisation from time to time. However, it would be in the interests of the country if premier scientific bodies like the Indian National Science Academy are asked to give their views. It is in the interest of science that important decisions on science are not taken by individuals without consultation of a cross-section of the scientific community. It is for this reason, as one of the biggest democracies in the world, we must plan for a system in which the difficulties under which scientists work are brought to the attention of the authorities concerned in as many ways as possible. The INSA is a body recognised for this purpose and would be happy to make its resources available to the Government in all possible ways, whether it is in planning, reorganisation of scientific structures, availability of experts or the evaluation of the scientific achievements of the country.

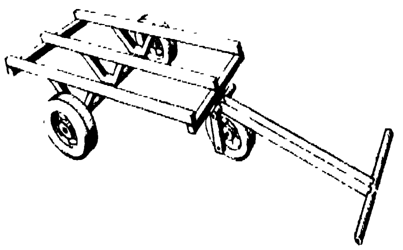
Whatever approach we adopt to improve economic conditions, the development of science in all its aspects is inescapable in a large country like India. We spend comparatively so little in R & D as a percentage of our gross national product. If this is increased even marginally, the inevitable progress of becoming a prosperous country through science and education will be greatly speeded up.

The Academy welcomes the statement of the Prime Minister that every effort will be made to ensure that no one in this country remains unemployed within a period of ten years. This, in our view, can be achieved only through a scientific utilisation of all our resources, material and human.

The Academy extends its fullest co-operation and support to the Government in its endeavours to eradicate poverty, to improve rural economy as well as to evolve plans for development through science and technology."

S. K. DASGUPTA
Executive Secretary
Indian National Science Academy
Bahadurshah Zafar Marg
New Delhi-110 002

Bullock cart design



The new bullock-cart design (Ideas & Inventions, June 1977) developed by the National Institute of Design, Ahmedabad, suffers from some glaring defects. Take, for example, the taper-roller bearings which are to be fitted in the hubs. This type of bearings is capricious, and require precise assembly. And if the bearings are not properly sealed and maintained, dust entering the bearing housings will cut the life of the bearings drastically. Again features which permit movement of the yoke in three planes are welcome, but the load still falls on the necks of the bullocks; there would even now be that sudden jerk when the bullocks start pulling the cart, and there is no new way to apply brakes except by pulling the rope.

Indeed, the NID design does not make any creative departure from the old design. While still making use of the skills and materials available in the rural areas, can't we break away from the existing design totally? Why, for example, should the bullocks " pull " the cart? Can't we evolve a design in which they push the cart? This may sound funny. Though it may not be possible to achieve such a design, it would help us to view the problem from other vantage points and there could be useful " fall-outs " from this exploration. Similarly, we have also got stuck with the wheels of the cart. The NID design suggests two wheels with pneumatic tyres. Owners of scooters and cars know the consequences of low tyre-pressures. Do we expect the bullock-cart owners to get tyre-pressures checked at the nearest petrol pumps regularly? Can they always carry normal loading on the carts so that the tyres are not overloaded?

P. P. DIXIT
5A, Parijat Society,
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Paldi, Ahmedabad 380 007

It will be helpful to use ball bearings instead of conical roller-bearings, and a brake may be applied to the front wheel for stopping the cart.

SUKUMAR MONDAL
P.O. Jote Shibrampur
Via Maheshtala, 24-Parganas
West Bengal

The author has failed to note the following: (1) the rim, hub, axle and spherical roller-bearings are readily available. There is no point in making the steel rim, wooden spokes and hub, and then fixing the conical roller bearings. Is it not necessary to fix a metal housing in the wooden hub for bearings?

(2) If a steel pipe is to be used for the axle beam, the diameter of the pipe will be large and finding a suitable bearing will be a problem.

(3) The author feels that making a solid tyre is as simple as fixing an old tyre after cutting off the side walls, but I wonder how this wheel will work on different ground levels.

The valuable point, however, is the nailing of rubber pads to the hoofs.

L. SHYAM PRASAD
H No. 54, Road No. 2
Hyderbasthi, Secunderabad 500 003

The new bullock cart design looks better than the conventional carts used in the Malnad area of Karnataka. But in the hilly tracts, a cart without brakes is dangerous to the bullock while going downhill. In the conventional cart, a round wooden pole which is tied with ropes just behind the wheel acts as a brake; by pulling hard the ropes connected to the yoke, the driver makes the pole press the wheels tightly so that the cart slows down.

B. S. VENKATESHA MURTHY
Customs Inspector
Someshwar 576 112

Cell separator fabric

" Indigenous cell separator fabric will boost battery technology," (Ideas and Inventions, June 1977, p. 57) does not mention whether the fabric developed is for the sealed type of nickel-cadmium battery or for the vented type. Sealed type batteries have no free electrolyte, and hence topping up is not required due to spilling or evaporation. Vented type batteries, which have free electrolyte, require non-woven nylon separators (felt type, bonded fibre type, closely woven type or thin film type); these separators need not have high absorption characteristics. For sealed type batteries, woven nylon separators absorb the required quantity of electrolyte (no free liquid in cell) and the entire electrolyte supply plus separation of electrodes, lowest impedance, etc are provided by the separator. Hence, these assume greater importance. So far, no indigenous sealed Ni-Cd cells are available in the market in India.

VASANTHA SETHURAMAN
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Bangalore 560 004

Dr. Shenai writes : **The write-up on cell separator fabric was based on published literature from abroad and on a press release issued by the synthetic fibre manufacturing firm (JK Synthetics Ltd, Kota), and widely published in the Indian technical press. (I myself had received a copy of the press release, being a Consulting Editor of a Hong Kong-based textile monthly.) Since the battery separator fabric is reported to have been developed by the firm in collaboration with LRDE, Bangalore, Mrs. Sethuraman may contact either or both of them for further information.**

More about trees

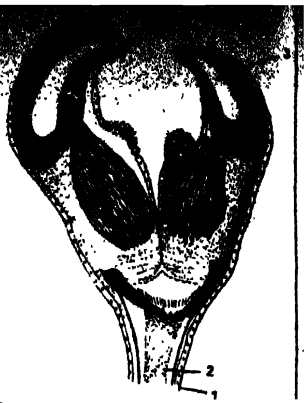
I read with interest the article, " Let's get to know our trees " (May 1977). I would like to add a few facts relating to the *karaya gum* tree (*Sterculia urens*). *Sterculia* is used as a homoeopathic remedy for alcoholism. It promotes appetite and digestion and lessens the craving for liquor. It regulates the circulation, is a tonic and anti-diarrhoeic, it also regulates the cardiac rhythm and acts diuretically.

N. SOLAIYAPPAN
ADM Sec. HQ. Coy
406 Signal Regiment
C/o 56 APO

Pipal leaves (" Let's get to know our trees — Fig family ", June 1977) can be used for beautiful paintings after removing the chlorophyll. The leaves are soaked in water for about 15 days and the chlorophyll is scraped off with a brush. The leaves are then dried for a day, after which one can paint on the leaves.

Y. PARVATHI
C/o Sri Y. K. Moorthy
24/889 Dargamitta, Nellore-3

1. Stalk
2. Axis of the stalk
3. Venom gland
4. Aperture of the gland



Venoms

The sketch of the sea urchin pedicellariae in the box item " The venom apparatus " (June 1977, pp. 32-33) in the article " Of those deadly denizens of the sea " was wrongly numbered. The correct numbering is above. In the same article, the word " testa " for the outer shell of sea animals should read " test ".

The title " Some stinging insects " on p. 52, as several readers have pointed out, was misleading. The article was originally intended to be on stinging insects, but since it didn't arrive on time, the article on scorpions was used, with a passing reference to some insects like bees and wasps in the box item " The child-killers ". (The title artwork was prepared earlier and could not be changed) —Ed.

Liquid crystals

Dr. N. V. Madhusudana's article on liquid crystals (June 1977, p 11) is interesting, though not complete Besides the books listed for further reading, I would recommend *Introduction to Liquid Crystals* edited by E. B Priestly, Peter J Wojtowicz and Ping Shing, and published by Plenum Press It gives a better and wider coverage.

ASHWIN I. MEHTA
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Thin films

The caption for Fig. 7 (April 1977, p. 16), in my article " Thin films ", needs to be slightly corrected It should be Thin film thermopile consisting of 42 Cu/Constantan elements capable of measuring temperature differences~ 10^{-8} °K (Developed at the Thin Film Laboratory, IIT, Delhi.)

I regret the error.

K. L. CHOPRA
Dean, Post-Graduate Studies & Research
IIT, Hauz Khas, New Delhi 110 029

Jaundice of the newborn

In the chart on p. 19 (" Of viruses and jaundice", August 1977) on the " Compartmentalisation of jaundice. . . .", physiological jaundice of the newborn which appears under Category II (Post-hepatic jaundice) should be under III (Pre-hepatic jaundice). This was due to oversight.

M. V. N. SHIRODKAR
Head, Department of Virology
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FOR THEIR EYES ONLY?

There is an element of the tragi-comic in the way decisions at the government level are taken in this country. Whether they concern food, education, health, housing, rural development, or even scientific research, the decisions are almost always made behind the back of those who are likely to be most affected by them. And the men who initiate and carry them through are again invariably the bureaucrats and administrators who perhaps sincerely believe that what they think or do is alone in the best interests of the people.

Take the case of the recent government decision to dismember the Council of Scientific and Industrial Research. The CSIR, over the years, had evolved into a premier institution spending the second largest amount of fund allocated for the country's science and technology budget. It had, in the past few years, initiated a number of moves for indigenisation and efficient use of its research and development efforts which had begun to show interesting results. But early last month a decision was suddenly taken to dismember it and attach 28 of its 44 constituent units to the various " user ministries "

The decision, apparently, was taken in the style of a coup. In late June, or early July, a former director-general of CSIR, whose tenure earlier was marked by frequent squabbles and a general lack of productivity, had a meeting with the Prime Minister The meeting led to a proposal from the Prime Minister's office to " restructure " the CSIR, followed by a discussion among some bureaucrats, and, finally, the approval by the Cabinet to the proposal, all within a period of one month. No one apparently knew of the quiet goings-on, not even the outgoing director-general, Dr. Y. Nayudamma.

Things, of course, had been brewing up for some weeks. Around mid-July, the government had announced the reconstitution of the National Committee on Science and Technology with Dr. Atma Ram, a former director-general of CSIR, as chairman. In a press interview, a few days later, Dr. Atma Ram made certain statements (favouring purchase of patent rights and import of technical knowhow rather than " rediscovering things in the name of self-reliance ") which caused considerable consternation in the scientific community. Even the governing council of the Indian National Science Academy felt compelled to join issue. In a resolution (reproduced on p. 5) made public in early August, it declared:

" It has become fashionable to accuse science and the work of scientists for various acts of omission and commission The failure to have good water supplies in towns and villages, poor quality of roads, unhygienic hospitals, poorly constructed buildings, lack of nutritious food, etc are not due to science, but due to poor management and administration, indecision at political levels and the stronghold of superstition on our simple folk."

This was unusual INSA has been a national body of rather sedate senior scientists, somewhat establishment-oriented, who are most reluctant to be drawn into any public debate Also, whatever the scientific norm, they argue, they could not possibly go public because almost all of science and scientific research in this country is under direct government control and government rules forbid any government servant, even if he is a scientist, to air opinions without the prior approval of his superiors.

What had then happened? Were there going to be any sweeping changes? And of what kind? And would the changes affect them? The resolution, which had been released to the press two days before the government decision on CSIR leaked out, also contains a note of warning: " We understand that science is being reorganised at all levels and the structure of scientific agencies is being altered . . It is in the interest of science that important decisions on science are not taken by individuals without consultation of a cross-section of the scientific community."

The consequences of such ad hoc decision-making for the country on programmes making use of science and developments from science have been discussed in SCIENCE TODAY from time to time. It is unfortunate that the present government should choose to continue to repeat the folly of its predecessors and deny this country the opportunity to discover a more meaningful course of development. And that, too, in the face of certain favourable factors which have emerged recently to our advantage.

The energy crisis and a growing ecological awareness has recently forced the world to look for low-cost energy technologies. But advanced countries with already high investments in high-cost energy technologies are not likely to change over easily to new systems. For us the problem does not exist. Rather, given our trained manpower and the broad infrastructure, it should be comparatively easy for us to develop and give a big push to processes based on the use of microbiological techniques or low-cost energy resources. Besides, expertise in low-cost technology should also give us an opportunity for closer interaction with a large number of countries in the Third World since such a technology would be clearly more in tune with their own general programmes of development.

Views are also gaining support in recent years that development based on low-cost energy sources is conducive to a more just and democratic system of government The argument runs thus Since high-cost technologies require huge investments in capital and other costs, they, in course of time, acquire a more and more authoritarian style of functioning, whose influence begins to impinge on the surrounding social and political systems. As against this, low-cost energy technologies, which require small investments and consequently carry much lower economic stakes, should promote wide dispersal and decentralisation of authority.

However, for a country whose industrial structure has been based mostly on imported technology, such a push towards low-cost technology would not only require a fierce political will but also the framework of a policy which has been evolved after intense nationwide discussions and debates. Indeed, wide-ranging interdisciplinary debates elsewhere involving extensive citizen participation have been found to help not only to gather diverse views so necessary for an objective assessment, but also to unravel facts which would otherwise have gone unheeded and which could have serious implications for the future. They also help to generate enthusiasm and, at the level of individual projects, a sense of involvement and personal participation among the workers.

Last, but not the least, a national consensus could indeed fortify the committed policy-maker's stand against the enormous pressures exerted by diehard vested interests, many-spangled multinationals and covert international agencies.

S.J.

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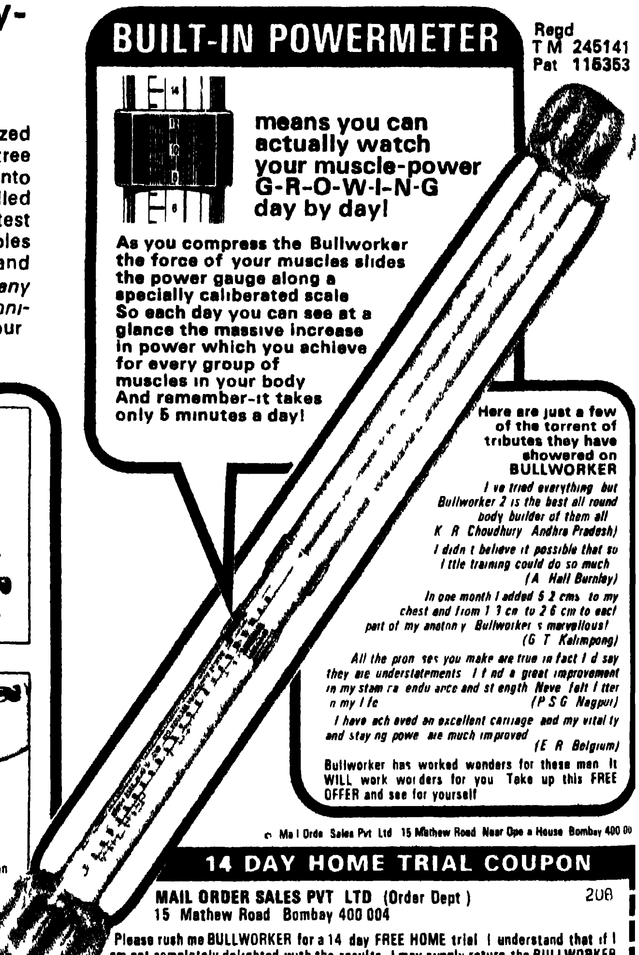

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(P S G Nagpur)

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(E R Belgium)

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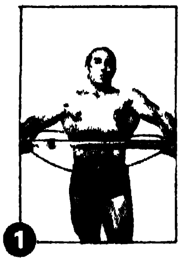

1

2

This exercise builds steel like rippling biceps

3

Here s how to attain that handsome athletic V shape

4

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5

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6

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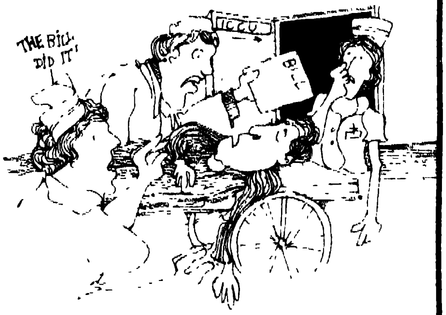
WHAT PRICE CORONARY UNITS?

"The costlier, the better" doesn't seem to be true in modern medicine. Often the reason for promoting a particular drug or equipment is that millions have been invested on researching and developing it.

The intensive coronary care units of hospitals are quite glamorous with their winking lights and oscillographs. However, a report in the *Britsh Medical Journal* (9 July 1977) casts doubt on their utility.

Two teaching hospitals in Nottingham (UK) admitted 2,000 patients with heart attacks over 32 months; about two-thirds of them went into the coronary units and the rest into the general wards, for want of beds in the coronary unit. The mortality of the men treated in the coronary unit was 15 per cent and among those in the ward it was 18 per cent — a difference considered not statistically significant. The success rate in reviving the heart in the coronary units was no better than in the wards.

It is true the allocation of patients was not random — the younger patients with more severe attacks were selected for intensive care. The Nottingham doctors who make the report conclude that though a specialised unit can provide better care, more evidence is needed to justify the cost of a coronary unit.



FUSION BY ELECTRON BEAM

The proponents of thermonuclear fusion by imploding fuel pellets with electron (and ion beams) (see SCIENCE TODAY, January 1977, p. 28) seem to have more than a talking point. Last year, the first evidence for electron-imploded fusion came from the Kurchatov Institute in Moscow. Now the Sandia Laboratories, Albuquerque, USA, also seem to have done the trick.

It was earlier thought that laser light would be ideal for achieving the high temperature and density that would produce fusion in a fuel pellet. However, the energy is more easily delivered by particle beams; and the pellets can also be larger, their exact shape not being critical (while in laser experiments, customarily, micropellets much smaller than the head of a pin are used).

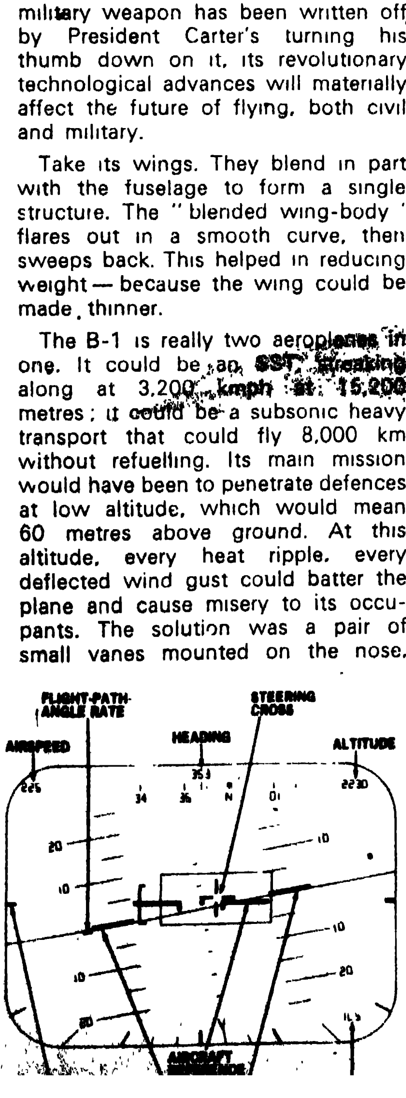
In the Sandia experiments, electrons were pulled from the cathode of an accelerator and accelerated towards the

B-1, THE BOMBER THAT NEVER WAS

Although the B-1 bomber as a military weapon has been written off by President Carter's turning his thumb down on it, its revolutionary technological advances will materially affect the future of flying, both civil and military.

Take its wings. They blend in part with the fuselage to form a single structure. The "blended wing-body" flares out in a smooth curve, then sweeps back. This helped in reducing weight — because the wing could be made thinner.

The B-1 is really two aeroplanes in one. It could be an SST streaking along at 3,200 kmph at 15,200 metres; it could be a subsonic heavy transport that could fly 8,000 km without refuelling. Its main mission would have been to penetrate defences at low altitude, which would mean 60 metres above ground. At this altitude, every heat ripple, every deflected wind gust could batter the plane and cause misery to its occupants. The solution was a pair of small vanes mounted on the nose, which twist and swivel automatically and cancel out vibrations in the plane's body.



Equally revolutionary are the B-1's avionics. A 20-cm TV screen called Vertical Situation Display (VSD) has been designed to take over the function of the usually numerous display panels and give all the standard information — altitude, airspeed, angle of attack — in digital format (see drawing). But the familiar dials giving this information were also retained — just in case. The pilot could also call up an infra-red image on his VSD screen to get a uniquely complete picture of what is happening.

And the B-1's fuel was meant to do double duty — it would serve as a stabilising agent, too. Fuel lines connect fuel tanks in the wing, fuselage and tail, and fuel could be pumped about automatically to obtain the centre of gravity selected by the pilot. Keeping the aircraft in the most efficient flying altitude, this would make the occupants more comfortable and also save fuel.

One manufacturing process used in the B-1 has been adopted already for the Space Shuttle. It is diffusion-bending, in which two pieces of metal heated under high pressure from a press, in a vacuum, diffuse into each other to become a single, shaped component which is stronger and costs less than a welded structure.

...THE CRUISE MISSILE WON THE VOTE

The cruise missile, which President Carter preferred to the B-1 bomber as a replacement for the aging B-52 bomber, is a revolution in weapons technology. As in the case of the neutron bomb (see SCIENCE TODAY, August 1977, p. 54), the traditional distinction between tactical and strategic weaponry is blurred.

The cruise "missile" is more a small pilotless Kamikaze bomber that hugs the ground, following an "electronic map" stored in its tiny on-board computer, and explodes within a few metres of its target. As it flies, a radar altimeter surveys surrounding terrain as the missile glides along at tree-top level, and compares it to the map. The 6.5 metre long missile can thus skim a mountain top, turn and hug the edge of a valley, skirt a radar installation and hit the target. It is available in two versions which can be launched from air or sea; it can be armed with a nuclear warhead or conventional explosives and targetted against a target, 2,880 km away, or sent to search out an enemy ship 550 km away.

The US Air Force version of the cruise missile was tested in May 1976. The US Navy's Tomahawk missile which made its first test flight in March incorporates an additional technology that permits it to be launched from either land or sea. For submarine launching, the missile is first propelled through the water and then into the air by a solid-fuel rocket booster. A small, efficient jet engine then takes over. This engine makes the cruise missile so cheap that counter-measures will be disproportionately expensive. Each Tomahawk is expected to cost only about $1 million when produced, compared to $102 million each for the B-1. Even the various ICBMs cost several million dollars each.

A WHEEL-CHAIR THAT GOES INTO A CAR

This wheel-chair developed by an Australian firm enables a physically disabled person to be transferred by an attendant into and out of a car without being lifted. The seat section with the patient sitting on it can be slid off a trolley and on to a metal base plate which replaces the front passenger seat. The car, however, has to be modified by removing the front passenger seat and replacing it by the base plate; a thin metal channel is also fitted on the inside of the door to guide and balance the chair as it slides in.

anode, where the fuel pellet is located. The beam current generated strong magnetic fields that focused the beam down to the 2-3 millimetre wide pellet. Wearing away of the pellet's outer layer generated an imploding pressure of about 5 million atmospheres, which crushed the pellet about a thousand-fold, raising its temperature to 5 million-10 million degrees Kelvin. The pellet absorbed about 40 billion watts of power in a pulse lasting 1/10,000,000 second. Much higher power and shorter pulses would be required for a fusion power plant using electron beam methods.

"CURING" THE COMMON COLD

The changing fashions in medicine are nowhere better seen than in the remedies for colds. Anti-histamines for colds were once the rage with doctors till it was found that a placebo (a blank pill) gave just as good results. Later came the biflavonoids (a group of complex organic substances collectively called vitamin P); these were proved to be equally useless.

Then came the shot-gun approach employing fixed-component formulations. Though the medical profession has repudiated this approach, pharmaceutical concerns have put out preparations containing a vaso-constrictor, a decongestant, an anti-histamine, an analgesic, vitamin C, etc. The anti-histamine has a side-effect, drowsiness, which is a factor in automobile accidents in the USA. The decongestant (generally phenylephrine) just doesn't work, because the dose is usually too small. The best-seller among the shot-gun remedies in the US was a timed-release formula which also contained small amounts of belladonna alkaloids; however, as the dosage is theoretically spread out over 12 hours, the user gets too meagre a dose at any one time.

Vitamin C in large doses has been advocated by Linus Pauling but other authorities are not so sure about it. Excessive doses can cause disabling diarrhoea, and also kidney stones in persons afflicted with gout. One study conducted in 1972 in Canada showed that persons given vitamin C experienced slightly fewer colds and illness, but the difference was not statistically significant.

Much research on cold remedies, according to *The Medicine Show*, a publication of the Consumer's Union, New York, is scientifically worthless because the term "cold" may designate not only identifiable viral respiratory infections but almost any congestion of the nose, caused by a variety of irritants. Added to the difficulty in diagnosis is the fact that it may be caused by any one of a group of viruses, currently estimated at about 100 in number.

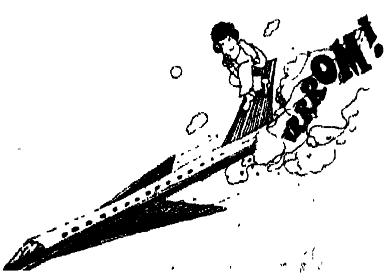
The effect of emotions on colds has been a complicating factor. At the Common Cold Research Institute in the UK, attempts are being made to isolate the psychological factor.

Medical advice is rarely required for the common cold. In fact, some authorities believe that any attempt to suppress the symptoms of a cold may actually prolong the infection. Others endorse the familiar folk remedies — aspirin, chicken soup — as being as effective as anything else

There is no real proof of the efficacy of bed rest in treating the common cold, but it may prevent one's passing on the cold to others. To minimise infection, Consumer's Union's medical advisers suggest cold sufferers should wash their hands frequently, for the hands are an important factor in the transmission of the virus.

SPIN-OFF FROM THE CONCORDE'S BOOM

It could easily be said that aeronautic engineers could learn one lesson from paleontology: that giant aircraft are likely to go the way of the diplodocus and the stegosaurus. The truth, however, is not so simple. Few will have a good word for the Concorde whose sonic boom has created problems for the airline that uses it. But this noise can be put to good use. It helps monitor meteorological conditions in the upper layers of the atmosphere which are difficult to study.



Strange noises were picked up by a microphone array set up at the Lamont-Doherty Geological Observatory in New York after 24 May 1976, when the Concorde began regular flights between Europe and Washington DC. They were inaudible to human ears, having a frequency of less than one cycle per second (the human ear can't hear sounds of less than about 16 cps), and it was calculated that they came from the flight path of the Concorde. The observations are interpreted as being due to the sonic boom bouncing off the stratosphere and the thermosphere at heights of 40·23 km and 121 km, respectively. Since the frequency of the sound is reduced by its passing through the rarefied upper atmosphere, measurement of the frequency gives an indication of the height at which the sonic boom is reflected; and observations on the sounds give the temperature and wind velocities at the reflection altitude. Describing the observations in an article in *Science* (1 July 1977), N. K. Balachandran, W. L. Donn and D. H. Rind of the Lamont-Doherty Observatory suggest that Concorde flights could provide a valuable probe for measuring conditions in the upper atmosphere.

SYNCHRONY OF MENSTRUAL CYCLES

Six years ago, a Harvard psychologist established that women living together tended to have synchronised sexual cycles, without establishing the cause.

This year, Michale J. Russell of the Brain Behaviour Research Institute, California, USA, presented evidence at the meeting of the American Association for the Advancement of Science in San Francisco that the effect is related to the sense of smell. He chose 15 volunteers aged 19-39 and a "sensory donor" for supplying the olfactory stimulus. The latter was a woman whose menstrual cycle was known to synchronise with that of a friend whenever they roomed together. She wore cotton pads under her armpits for 24-hour periods and gave the collected perspiration to Russell, who mixed it with ethanol and applied it to the lips of volunteers over a period of four months. 'Control' subjects received ethanol alone.

The experimental subjects who started their menstrual periods an average of 9·3 days away from the donor in January, had, by May, reduced the gap to 3·4 days. The controls showed no significant change.

Russel says that even other body odours (saliva, vaginal secretion) could change the menstrual cycle.

"CURRENT AWARENESS" IS COSTLY

Among the items that add to the cost of scientific progress, which is admittedly expensive, is the high price of scientific journals. A survey published in *Science* (29 July 1977) shows that their prices have little correlation with the cost of production or the cost of living. One reason for their high price is the increasing specialisation among scientists. As journals become more specialised in scope, their subscribers become fewer and the cost per subscription rises.

The survey shows that the prices of scientific journals are increasing faster than prices of journals for other subjects, being many times higher. The average prices of physics journals have been increasing faster than prices of chemistry journals. In fact, the 1976 index figure for physics journals is more than twice that of the US Consumer Price Index for June 1976. *Chemical Abstracts* (not a primary journal) is even offering its " 10th Collective Index for 1977-82 " under one of several instalment plans ! Its price is $7,750 (about Rs. 69,000).

At least in the case of American journals in the physical sciences, a major factor in the price rise is the increased number of pages rather than the cost of printing and paper.

The implications can be serious, say the survey's authors, F. F. Clasquin and Jackson B. Cohen, because scientific journals thus consume a disproportionately large share of academic libraries' periodicals budget. Many libraries are already resorting to photo copies or inter-library loans for meeting readers' needs.

THE MUSSEL'S MUSCLE-POWER

The lowly mussel that clings to wave-battered shores may have something useful to surgeons and dentists who are constantly in search of adhesives resistant to movement and moisture. A number of research teams are now working on the chemical composition of the byssus, the mussel's unique holding device. A vast number of manufacturing processes in which adhesives play a fundamental role may also benefit from the knowledge, according to an article by Arnold Tamarin in *Natural History* (May 1977).

The byssus is a cylindrical rod extending from near the middle of the straight edge of the tightly closed shell. Attached to this rod, the byssus stem, are a number of threads each ending in a flattened disc, the " attachment plaque ", that adheres strongly to the surface of rocks. Studies in a laboratory aquarium have shown that a mussel attaches itself thus : the shell opens slightly and the foot is extended and applied against the surface. A turbid material flows out of one end of the foot, the foot is then withdrawn, leaving behind a disc and a thread that emerges from a longitudinal groove on the surface of the foot.

Micrograph showing the flattened disc, with which the mussel holds fast to various surfaces, seen at the end of a thread

At least five different substances are synthesised in the formation of the byssus — a form of collagen, a type of mucus, a phenolic protein, an enzyme that converts the phenolic protein into a tanning agent, and a yet unidentified substance. The formation of the adhesive disc is not yet understood.

It appears that the threads serve as guy wires, cemented by the disc at one end and attached to the stem at the other. The flat corrugated segment of the thread next to the stem acts as a shock absorber which stretches out in response to the buffeting of the waves.

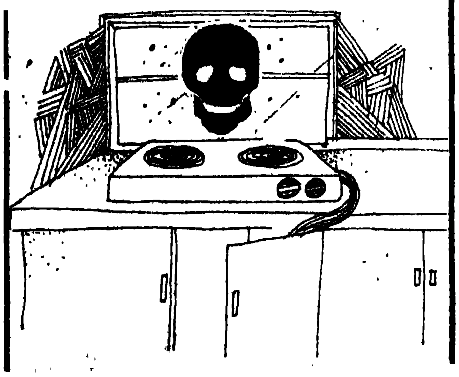
Weaving the tough byssus threads into gloves, scarfs and purses was long a home industry on the Mediterranean coast, but is now a forgotten art.

GAS-COOKING AND RESPIRATORY DISEASES

Respiratory diseases in children have been traced to the cooking gas used in homes.

A report on the study of environmental and socio-economic factors in causing the respiratory diseases in children (*British Medical Journal*, 16 July 1977) shows that boys and girls from homes in which gas fuel was used were found to have more coughs, colds and bronchitis than those from homes where electricity was used.

The effect of the fuel was invariably felt irrespective of the factors such as age, social class, latitude, population density, overcrowding, outdoor pollution, etc. Children, aged between 6 and 11 years, numbering 5,758 from 28 areas of England and Scotland formed the study population. Girls were more affected than the boys. Probably, this is due to their spending more time in the kitchen. If the risk is purely dependent on overexposure, increased ventilation might reduce the pollutant level, say the researchers.



Emissions from cookers were found to be constituted of nitrogen, oxygen, carbon dioxide and water vapour with small amounts of methane, ethane and other hydrocarbons.

CONE MAGNET PICKS UP MORE

For the benefit of the iron and steel industry in moving materials and collecting steel scrap, a new device has been suggested.

In the usual flat-faced electro-magnets, only 1/20 of the pick-up capacity is utilised. But cone-shaped electro-magnets would increase the pick-up capacity many-fold. John Peace of British Steel Corporation's (BSC) Teesside Laboratories has shown that when a steel cone is attached to the underside of an electromagnet, it increases the pick-up of steel scrap by up to 100 per cent. The cone goes deep into the scrap pile, thereby increasing the magnetic field and extends the effective pick-up range. Also, addition of the cone adds to the surface area of the lifting face to which scrap can cling. And at the apex of the cone the density of the magnetic flux will be very high.

The BSC has licensed a Swansea concern to manufacture a range of cast steel cones for consumers outside the Corporation. The ratio of cone length to diameter is critical for maximum pick-up and the manufacturers propose to produce off-the-shelf magnets with a length 1·5 times the diameter as the best average.

HAIR ROOT ANALYSIS

The latest experiments in hair root analysis have strengthened the feasibility of measuring the elemental contents of biological tissues.

A report published in *Science* (15 July 1977) says that single hair root analysis by proton-induced X-ray emission (PIXE) has shown correlation between the elemental content of hair root and certain standard clinical assays of blood. (See also SCIENCE TODAY, March 1974, p. 54.)

In all specimens, phosphorus, sulphur, chlorine, potassium and calcium were detected. Manganese, silicon, zinc and iron were also detected in 30 to 56 per cent of the specimens. Non-detection of certain elements can be due to their concentration being below PIXE detection limits.

An interesting fact that emerged was that the iron content is correlated with the sex, being higher in male hair root samples.

To reinforce the suitability of hair root as a biological sample, further research is required. For, whether the sex, age, colour or ethnicity of the individual has any effect on the hair root analysis is not yet known.

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NEW ODOURLESS GARLIC

SUNDAY STANDARD

Vijayawada Sunday October 17 1976

Raw Garlic is anti-bacterial

NAINI TAL Oct 29 (Samachar)

Raw garlic possesses anti-bacterial property against a number of micro-organisms including those which are resistant to commonly used anti-biotics This is revealed in researches conducted at the Pantnagar University. According to the researchfindings, anti-bacterial property of garlic is lost on boiling

Eve's Weekly

July-17-1976

AYURVEDA IN YOUR HOME

Suresh Chandra Chaturvedi

GARLIC

Regular use of garlic helps the digestive system and removes gas and constipation It increases the blood, cures chronic cold and cough Gastric troubles are cured by taking garlic every day

THE TIMES OF INDIA

BOMBAY DEC 3 1976

Eat Garlic and Cut Cholestrol

NEW DELHI, December 2 A medical study has revealed that garlic is effective in reducing blood cholestrol An experiment by Dr R C Jain, pathologist at the University of Benghazi in Libya has now shown that garlic reduces the cholestrol level

He did the experiment on rabbits which he fed with a diet containing large amounts of Cholestrol for 16 weeks Their aorta (main blood vessel) and liver were deposited with cholestrol but after giving them garlic, he noticed that the fat dissappeared and the blood cholestrol came down Dr Jain has reported the results of his experiment in The Journal of Indian Medical Research" How exactly garlic brings down cholestrol level is however, not clear, Dr Jain said-Samachar

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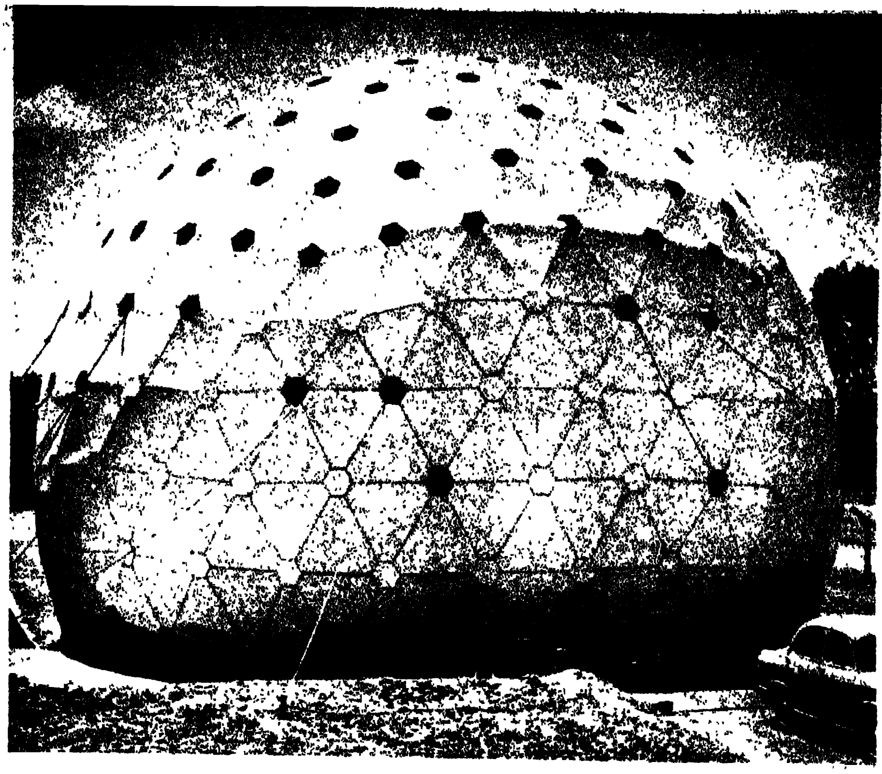


This 16·5 metre fibreglass reinforced plastic radome made at the National Aeronautical Laboratory, Bangalore, symbolises the strides India has made in composites technology — combining two or more different materials to produce something superior to the components. Here's an account of . . .

THE MANY USES OF COMPOSITES

S. RAMASESHAN
N. BALASUBRAMANIAN

Modern technology places severe demands on materials. The requirements are so self-contradictory that a single homogeneous material can hardly meet them. Hence materials have been combined to form composites. The combined properties are not only superior to the properties of the individual components but also to their sum. Frequently, composites are endowed with new properties which the constituents do not have. The idea of composites is not new but the technology has grown rapidly only in the last 15 years, so much so that composites have revolutionised the attitude to engineering design and have led to structures which are technically and aesthetically superior. Composite materials are being tailor-made today to obtain the required mechanical properties as well as the electrical, optical, thermal, magnetic and superconducting properties. And they have special significance in a world with depleting natural and energy resources.

Since the composites industry is science-based and labour-intensive, it is particularly suited to India. Through innovative uses, composites can play a significant role not only in aerospace but also in production machinery, boats, silos for grain storage, transportation, sports equipment and in a variety of general engineering applications.

Composites can be defined in many ways. However, for the present discussion, we shall define them as a combination of two or more chemically distinct materials with a distinct interface separating them. Thus, they should be distinguished from *alloys*, in which the mixing of two or more components takes place at an atomic level, and there is no distinct interface between them. As an example of a composite material, we may consider a ductile matrix (resin or metal) reinforced by a stronger but brittle fibre. The reinforcement can also be in the form of particles, flakes or ribbons. The matrix is not only strengthened but made tougher or more fracture-resistant by the reinforcement.

There are many examples of composites in nature. Bone, for instance, is a composite of the mineral hydroxy apatite and the polymer collagen. Nature has evolved this composite structure over millennia. The bonding between the two is so good that bone is stronger not only than collagen but pure apatite itself. How is this possible? Hydroxy apatite is a strong brittle material. Small cracks can develop in any material under stress but they are dangerous in a brittle material. At the bottom of a crack the stress gets concentrated and causes the spreading of the crack. In the case of ductile materials, the high stresses at the tip of the crack are relieved because the material flows plastically under stress. Cracks in a brittle solid can be stopped if we provide weak interfaces. In bone a crack which occurs in the hydroxy apatite is 'stopped' at the point where it meets the apatite-collagen interface. The small cracks are prevented from propagating. Thus, bone combines the 'stiffness' of apatite with the crack-resistance of collagen, producing a composite material which is far superior to each of its components. Essentially similar considerations apply to many of the examples we will be considering in this article.

Consider another example: if a sharp notch is cut on the surface of a bamboo pole which is then bent, it does not snap. On the other hand, splinters are peeled off near the notch but no crack propagates into the material. In this case the weak interfaces along the fibre virtually disconnect the crack from the material on the other side of the fibre. In effect, the cellulose fibres act to 'deflect' the cracks that start to propagate within the lignin matrix.

The above two examples indicate that the matrix and the reinforcing material can mutually act to prevent crack propagation in each other and to obtain high strengths. The properties of the composite depend, of course, on the properties of the reinforcement, of the matrix and of the interface between the two (see box on p. 14). (The bamboo is also protected from buckling by the cylindrical struts on the outside.)

Ancient civilisations had designed a number of composites purely from empirical considerations. The use of straws in bricks was known long ago in India. The presence of chopped straw prevents the propagation of

Wood is a composite of cellulose fibres in a matrix of lignin. This electron micrograph of a cross-section of aspen (enlarged 11,900 diameters) shows the lumen or cell cavity (pale central object) surrounded by the wall of a cellulosic cell (grey portion); the darkest material is lignin (Courtesy: *Scientific American*)

cracks developed when the wet clay dries rapidly in the Sun. The South American potters of Maya and Inca civilisations used plant fibres instead of straw. The Eskimos had to build their houses with ice, which is so brittle that cracks can run through the ice for kilometres. But it was common knowledge among these primitive people that if only they could put in some moss (two to four per cent) in water and freeze them together to form a composite, the ice could be converted into a new material which would not crack even if hammered. They also knew that the sea-ice, on account of the salt crystals dispersed in it, would not crack as easily as fresh water-ice would. The Mongolians used a laminated composite of horn, bone and wood to make bows. The Egyptians seem to have understood that the properties of wood can be improved by cutting it into thin veneers and gluing them together to form cross-plies. This results in plywood which minimises shrinkage and swelling when moisture is absorbed and also has good strength properties and resistance to splitting. The Samurai swords of Japan were laminated composites which combined different steels to achieve the desirable properties of (*a*) an exceptionally hard (martensitic) edge, (*b*) a tough, soft core, and (*c*) sides or covers of intermediate hardness. The swords were made by a laborious process in which all the constituents were hammered out, folded over and hammered out and welded again until a highly laminar structure was achieved. In the finished blade, there were thousands of layers of highly oriented fine-grained steel.

Fibres

The modern technology of composites has been made

Principles of reinforcement in composites

The principles of reinforcement in composites can be understood by a simple application of Hooke's law. When you load a bar, of, say, a metal, it gives way or stretches. According to Hooke's law, the bar of length l stretches by an amount Δl, which is proportional to load L, provided L is small.

$$\Delta l \propto L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

For the same load, bar of twice the length will extend by ($2\ \Delta l$). To get a number which is characteristic of the material and does not vary with the different shapes of the same material, we choose to use a ratio Δl to l, known as strain ε. Similarly, the ratio of load to the area of the bar, A, is independent of the size of the bar. This ratio is known as stress, σ. It is more useful to write Hooke's law in terms of stress and strain, as

$$\sigma = E\,\varepsilon \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where the constant of proportionality E is the Young's modulus and is a property of the material. A material is very stiff or difficult to deform if its E value is high. We have so far considered the case of a homogeneous material. For the case of composites containing a matrix and a reinforcing phase, say, a fibre, the equations have to be modified.

In the case of ideal fibre composites, the matrix material is reinforced by fibres which are uniform, continuous and unidirectional. Such a composite is shown in Fig. 1. The fibres are gripped firmly by the matrix so that there is no slippage at the fibre matrix interface. Under these conditions, the total load L_c is shared by the fibre and the matrix.

$$L_c = L_m + L_f \quad \ldots\ldots\ldots\ldots (3)$$

where L is the load and the subscripts c,m,f refer to the composite, matrix and fibre, respectively, in terms of stresses

$$\sigma_c A_c = \sigma_m A_m + \sigma_f A_f \quad \ldots\ldots (4)$$

where A is the area. Since the fibres run throughout the length of the specimen, the areas can be replaced by volume fractions as follows:

$$\sigma_c = \sigma_m V_m + \sigma_f V_f \quad \ldots\ldots (5)$$

The equation represents the rule of mixture for stresses. The ' no slippage ' condition implies the matrix and fibre extend by equal amount when stressed. Hence the strains in the matrix, fibre and composite are all equal.

$$\varepsilon_c = \varepsilon_m = \varepsilon_f \quad \ldots\ldots\ldots\ldots\ldots (6)$$

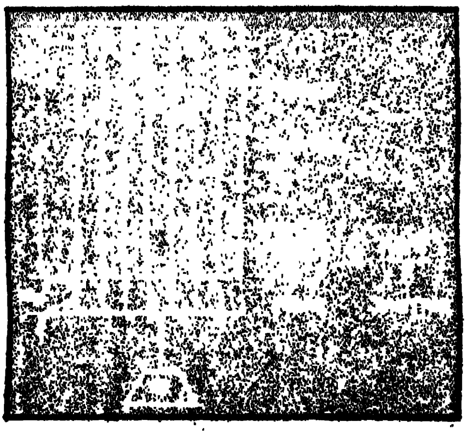
As a consequence, equation (5) can now be rewritten to give the rule of mixture for modulii. Equation (4) also enables a comparison of loads carried by the fibre and the matrix when the matrix and the fibre are deformed elastically. Equation (6) can be rewritten in terms of stresses and modulii, E using Hooke's law,

$$\frac{\sigma_c}{E_c} = \frac{\sigma_m}{E_m} = \frac{\sigma_f}{E_f} \quad \ldots\ldots\ldots\ldots\ldots (7)$$

or

$$\frac{L_f}{L_m} = \frac{E_f}{E_m} \times \frac{V_f}{V_m} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

Fig. 1



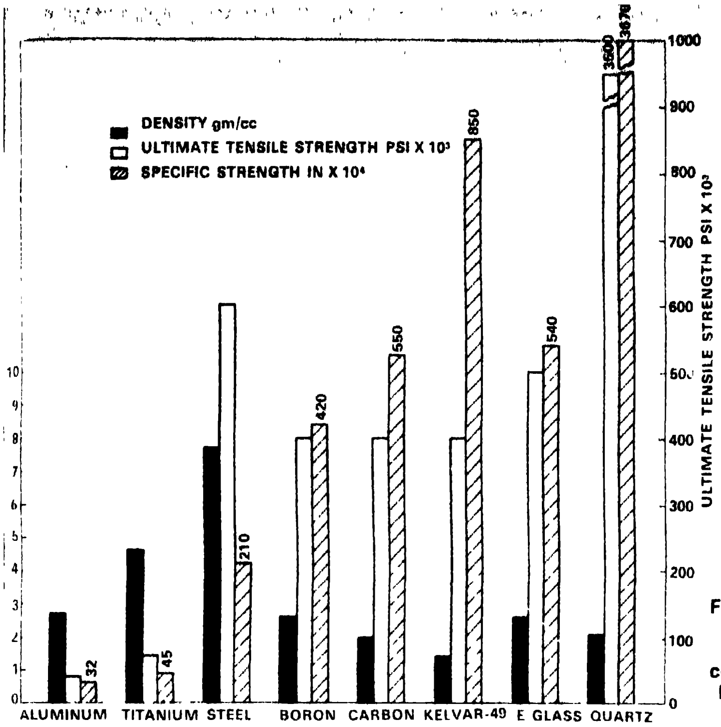


Fig. 2 Specific strength of fibres in comparison to high-strength alloys

possible by the development of high performance reinforcements, usually in the form of fibres. These fibres are put in a ductile matrix such as a resin or a metal.

Interestingly, the fibres available today are of materials that were considered brittle and unusable until recently. The properties of some of the fibres are shown in Figs. 2 and 3 along with the properties of high-strength alloys (combination of metals). We see that a quartz fibre which has one-fourth the weight of steel, is some 16 times stronger than the latter. But quartz fibres are difficult to grow and are very expensive. The glass fibre is probably the most widely used and is the only fibre available in India commercially. Glass fibres can be drawn from molten glasses of the appropriate composition. In the marble process, the refined glass is first made into marbles which are annealed and subsequently melted into an electrically heated fiberising element, referred to as a bushing. In the direct melt process, refined glass is fed directly into the bushing. Commercial bushings are made of platinum and contain thousands of orifices. Although glass fibre has high strength (500,000 pounds per square inch or 500,000 psi; 1 psi = 0·07 kg per cm^2), its use will always be restricted by its low stiffness (10 million psi).

The carbon (C) fibre is about six times as stiff (60 million psi). When C fibres were first available, they were so expensive that only aerospace applications could justify their use. Recent developments have changed the picture. Most frequently, C fibres are made by the controlled heating of organic fibres, similar to ' synthetic ' fibres used in fabrics. High-quality fibres are produced beginning from polyacrylonitrile (PAN), though even rayon can be used. The cost of PAN-based C fibres is 32 dollars (Rs. 300) for a pound. (These are not yet available commercially in India.) Sometimes, C fibre is made using the acrylic fibre but the resulting fibre lacks the superior properties of PAN-based C. Recently, there have been improvements in methods of producing PAN itself which have led to a reduction in cost of about 30 per cent.

An alternate but cheaper route to C fibre starts with pitch as a raw material. The pitch is heat-treated to form a liquid crystal phase called mesopitch which is subsequently drawn into filaments at high temperatures. The idea is to freeze in the directional alignment of molecules found in the liquid crystal phase. The pitch-based C fibres were introduced by Union Carbide of USA last December under the trade name Type P and sell for $20 (Rs. 180) per lb (454g). Today they lack the tensile strength of the PAN-based C but the strength of

Usually the fibres have modulii 10 times or more compared to the matrix. Hence, in a composite with 50 per cent volume fraction, the fibre carries a load 10 times or more than the matrix.

These ideas can be modified in a rather straightforward manner in a practical situation where the fibres are available only in short lengths or are broken and, therefore, discontinuous. Calculations show that if the length-to-diameter ratio or the aspect ratio of the fibre exceeds 10, the efficiency of load transfer from the weaker matrix to the stronger fibre is still around 98 per cent compared to the ideal case. The surface area of the fibre is so large that the load transfer at the interface is still very efficient even if the bonding is not perfect.

The maximum strength and modulus are realised in a composite along the direction of the fibre. Hence the properties of the composites can be varied by orienting the fibres appropriately. The properties of such a composite can be calculated using the rules of mixture and by taking into account corrections due to orientation dependence of fibre properties, stress concentrations at fibre ends, slippage at the fibre-matrix interface, etc. S. R. & N. B.

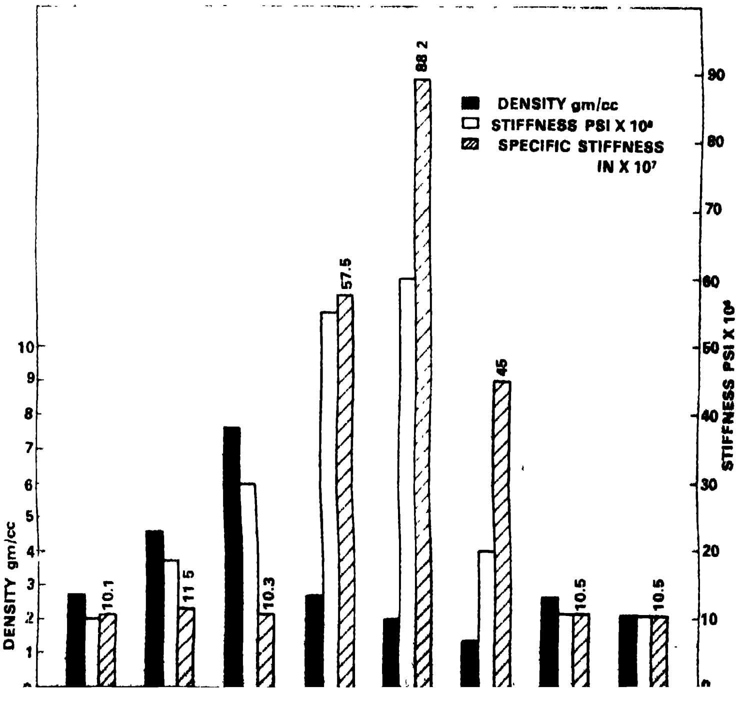


Fig. 3 Specific modulus of fibres

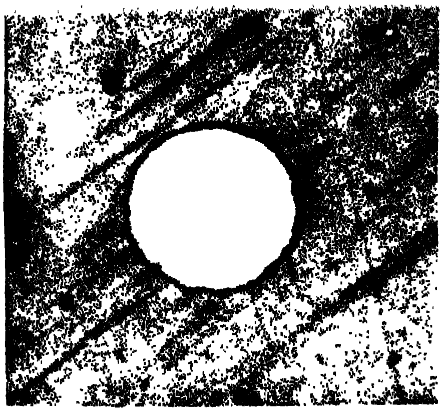


Fig. 4 Organic fibre in polyester matrix developed at NAL (diameter of the fibre 30μm)

the fibre is bound to improve in the near future. It is the pitch process which may help us realise the dream of a five dollar per pound carbon fibre. Until we get to this stage, the search for a cheaper fibre with properties intermediate between those of carbon and glass is justified.

The answer here may be the organic fibres. The best of them, Kevlar-49 developed by Du Pont, has the strength of glass fibres, twice the stiffness but half the density, and it sells for about five dollars a pound. An experimental organic fibre developed at the National Aeronautical Laboratory (NAL), Bangalore, is shown in Fig. 4. These fibres being organic have a better interface with plastics than do the inorganic fibres. Unlike glass fibres, they do not lose part of their strength while abrading against each other. Scanning electron microscopy shows that composites with organic fibres have an intrinsically low compressive strength. The difficulty is overcome by using them in hybrid composites with fibres which are strong in compression, such as glass or carbon.

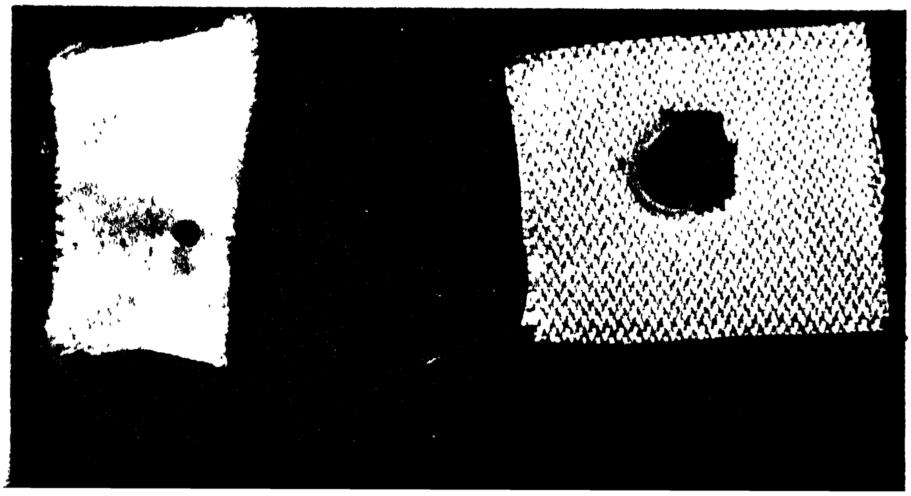
While the main interest in the fibres mentioned above is in their mechanical properties, there are other fibres which are very useful because of their thermal properties like that of a high melting point and low conductivity (thermal insulation). An example is the high silica fibre (Nalsil) developed at NAL. The process takes advantage of the fact that E-glass fibres are available in the country. These contain 55 per cent silica and 45 per cent of other oxides which are removed by leaching with acids, which is quite an economical process. The high-silica fibre, when introduced into a phenolic matrix, gives a composite which is being used as ablative (heat-shielding) material in re-entry vehicles, although this may be replaced by carbon-carbon composites in some ablative applications. Fig. 5 indicates the thermal resistance of a Nalsil fabric. An oxyacetylene flame (1700°C) held at a distance of 2·5 cm can burn a hole in an E-glass fabric in less than two seconds; under similar conditions it takes 150 seconds to burn through the Nalsil fabric. This duration is adequate for re-entry applications.

A widespread application for Nalsil will be in the insulation of large furnaces resulting in energy savings. The fibre is light and, therefore, costs less to transport. It is possible to use graded insulation, that is, use a thin layer of alumina in the hot portion (temperature above 1000°C) near the furnace and use Nalsil for the major part of insulation.

Fabrication of composites

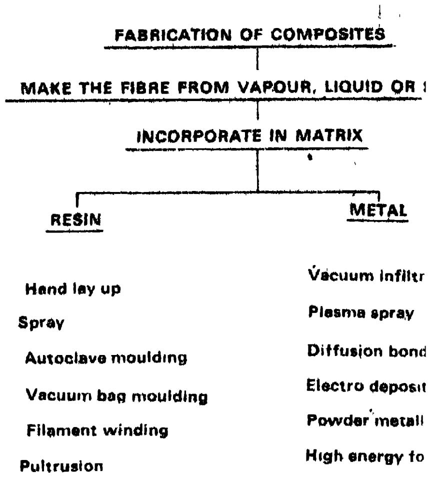
In making the final composite, of course, the fibres have to be situated in the matrix in the definite desired configuration. Some composites require the fibres to be placed parallel to each other, others require a random distribution. Some depend on a strong fibre matrix interface for their specific function, while weak bonding is important for other properties. Therefore, in each case, an appropriate method of introducing the proper fibres into the proper matrix must be found. There are a variety of such techniques (Fig. 6). Resins have been developed with the desirable properties such as (*a*) control of curing, hot or cold, (*b*) flexibility and viscosity which can be varied by adjustments in composition, and (*c*) storage for long periods until catalysts and accelerators are added. Some of them can be stored in a state of partial cure which makes it possible to pre-impregnate the fibre by resin and use the prepregs when required to make the products. These properties make a wide variety of fabrication methods possible.

Fig. 5 Heat resistance of Nalsil determined in a burn-through test



The simplest process for making reinforced plastics is that of placing, manually, reinforcements (say, fibreglass) and resins on a shaped mould (made of wood or plastics) and using squeezers or rollers to push in the resin and remove the air bubbles. Thickness is controlled by the number of layers of material placed against the moulds. Variations of this process include using heat to accelerate the cure or using a vacuum bag, pressure bag or autoclave to permit the application of pressure against the laminate to force out air (to reduce voids) and eliminate excess resin (to increase the glass-to-resin ratio). In the *spray-up process*, glass fibres are ejected into a resin stream and the mixture is directed at the mould. The *filament winding process* uses continuous strands and the product is in the shape of a surface of revolution. The strands are fed through a resin bath and wound on a suitably designed mandrel. Alternately, filaments coated with resin (prepregs) can be used. The winding machines are similar to lathes. The *pultrusion process* is analogous to extrusion in the case of metals. In this process, continuous

Fig. 6



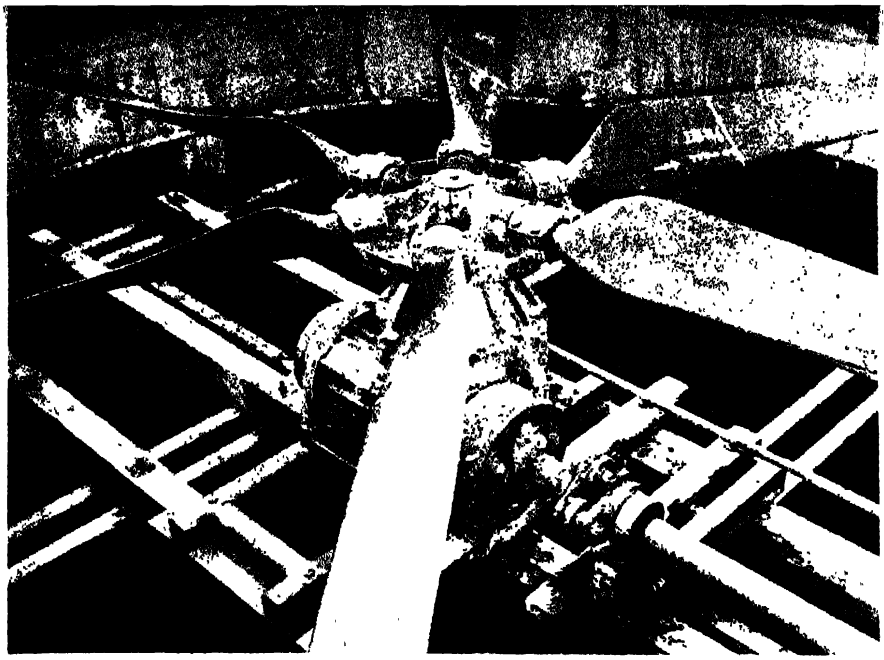


Fig. 7 FRP blades for cooling tower fan

reinforcements are fed through a resin bath and pulled through a die which determines the geometry and the resin content. A section of the die is heated to cure the composite.

Some of these methods have been employed at NAL to produce fibreglass reinforced plastic (FRP) components for various applications. A 16·5 metre radome (or a dome-shaped weather-resistant FRP covering for radar equipment) designed and built by NAL is shown on p. 13. FRP was chosen for this application since it is both transparent to radar waves and can meet the structural requirements. The structure has to withstand winds with speeds of 240 kph, erosion due to dust, corrosion due to salt in coastal areas, loads due to snow accumulating on the top, and solar radiation. The material has to undergo sufficient environmental testing before being selected for this application. The energy of chemical bonds in plastics is about the same as the energy of ultraviolet radiation from the Sun. Hence solar radiation can reduce the strength of plastics by breaking up the chemical bonds. Moisture can seep along the fibre, just as oil is sucked up by the wick of a lamp, and this would degrade the bond between the fibre and the plastic. Protective coatings can solve these materials problems. NAL now has the capability of designing and building radomes up to 30 metres in diameter with a radar transmission efficiency of 90 per cent.

We have developed more recently FRP tubes with controlled porosity. These can be used as a structural back-up support for the membranes used in desalination plants. Since these replace metallic tubes (stainless steel, for instance), which are more expensive and difficult to drill accurately, this development will lower the cost of desalination plants. We have also developed FRP containers for transportation of chemicals. In these applications, a good design is essential, since the structure must not only carry the weight, withstand splashing of acids, etc, but also must be able to resist failure for long periods. Expensive failures have occurred as a result of bad design and lack of non-destructive evaluation before the tank was loaded. The intrinsic advantages, however, are obvious, since the container is lightweight which means less energy is expended in transportation.

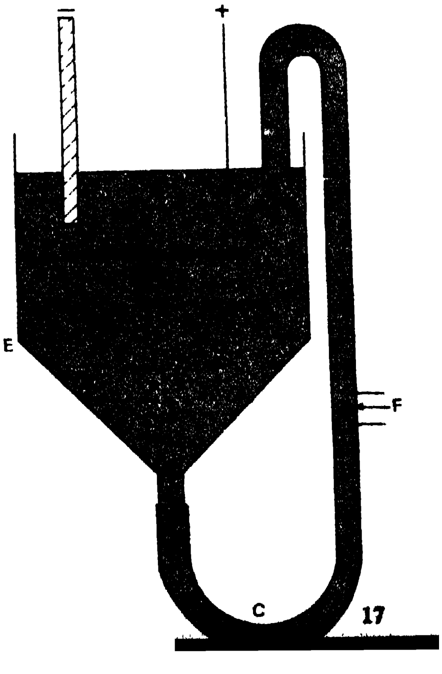
We have developed cooling tower fan blades which are part of every major thermal power station — up to 7·5 metres in sweep. Fig. 7 shows a set of six FRP blades developed at NAL and installed at the cooling tower of the NAL wind tunnel centre. These blades consist of FRP skins and polyurethane foamed *in situ*. Their low weight compared to wood results in reduced power consumption FRP can replace the traditionally used wood, which has the problem of warping, and aluminium, which corrodes easily when stressed. Other applications that have been developed at NAL include FRP insulating tubes and arc chambers for the electrical industry, and cyclone separators used in the chemical industry as dust collectors for separating corrosive mists from an air stream.

But resin matrix composites are not suitable for continuous use at temperatures above 250°C. For use at temperatures above this limit, metal matrix composites have been developed. Some methods of producing metallic composites are shown in Fig. 6. In the vacuum infiltration process, fibres aligned in a mould are infiltrated by the molten metal in a vacuum environment. This technique has been developed at NAL and applied to the preparation of composites of aluminium reinforced by stainless steel wires. This method will be used for the preparation of composites of tungsten fibres in a nickel matrix for use in aircraft gas turbine engines.

The method of *plasma spraying* used for boron-aluminium composites, for instance, employs a plasma torch which sprays matrix materials in the form of liquid droplets onto a rotating mandrel covered with aligned fibres. Composite tapes formed this way can be consolidated into structural parts by *diffusion bonding*. The diffusion bonding process of combining filaments with matrices such as aluminium and titanium involves the use of pressure and temperature. The matrix is in the form of foils, and fibres are laid on them in predetermined orientation and spacing. Alternate layers of metal foils and reinforcing fibres can be arranged to get the desired volume fractions. The whole assembly is then heated to develop bonding by diffusion.

Metallic composites can also be prepared by *electroforming*, that is, by electroplating the matrix on fibres wound on a mandrel or by co-depositing the metal matrix and dispersed particles on to a substrate. The latter have applications as cutting tools. Electro-deposited composite coatings consisting of a metal matrix

Fig. 8 Apparatus for depositing particle dispersed metal composite coating. A — Top of the electrolyte; B — Connecting tube; C — Peristaltic pump; D — Inlet port; E — Cone shape vessel; F — Air sucking point



and co-deposited dispersed particles impart wear resistance, dry lubrication and creep resistance. Fig. 9 shows the cross-section of a composite of nickel reinforced by silicon carbide particles. The particles are seen to be distributed uniformly. Electroforming has the advantage of combining the fibre or particles with the matrix at low temperatures so that thermal degradation of the fibre or particles is avoided.

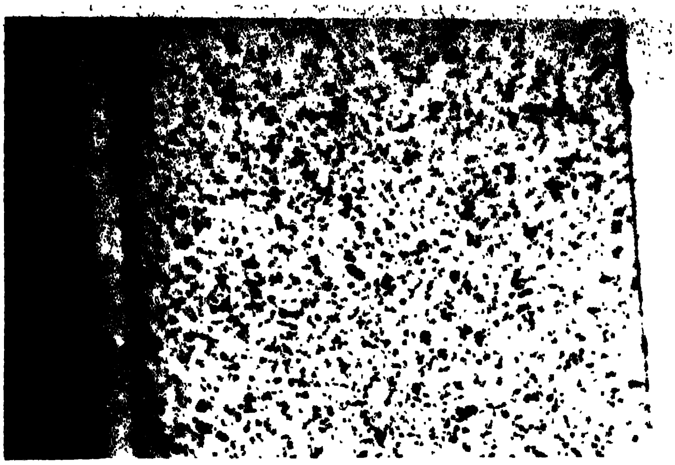


Fig. 9 Cross-section of a silicon carbide reinforced nickel composite (particle size is 2μm)

Composites have been produced by *powder metallurgy* techniques. The metal matrices in the form of powders are mixed with whiskers or chopped fibres. The combination is consolidated by pressing, sintering or hot isostatic pressing. In-situ fibering of second phase particles can also occur in a compact during hot pressing. These techniques are applicable to ceramics also. High-energy forming methods such as explosive forming and pneumatic impaction have also been used for making metallic composites.

A radically different method is the simultaneous growth of the reinforcing and matrix materials from a single melt. In *eutectic* solidification, two phases crystallise from the liquid. If the growth rates of the phases are compatible, one of the phases will crystallise out in the form of aligned fibres, the other forming the matrix. Nickel and cobalt alloys reinforced by tantalum carbide fibres have been obtained by unidirectional solidification and have properties superior to nickel base superalloys.

Inexpensive composites for less sophisticated uses

The spectacular development of high-performance fibres and composites should not obscure the fact that the principle of composites can be applied to several more common engineering materials, some of which are inexpensive and are readily available in India. Natural fibres such as sisal, ramie and jute have strengths exceeding 1,00,000 psi, and modulus of 10 million psi (similar to a high-strength aluminium alloy). However, they absorb moisture which causes swelling, increases weight and decreases mechanical properties such as tensile and creep strength. Moreover, they are vulnerable to attack by insects and fungi. These problems are overcome by incorporating them in a protective plastic matrix, impervious to moisture. However, an accidental crack in the matrix can expose the fibre. Therefore, development work to improve the moisture resistance of natural fibres is necessary. In the chemical structure of jute, oxygen and hydrogen atoms combine to form a group called the (OH) group. The presence of (OH) groups in jute is responsible for its moisture absorption. However, the complete removal of (OH) groups would make the structure of jute collapse. Hence, we have developed a chemical treatment which partially removes the (OH) groups, thus reducing the moisture absorption of jute by a factor of three. The strength, however, is reduced by only 15 per cent. The chemical treatment also prevents jute from absorbing resin *into* its tubular structure.

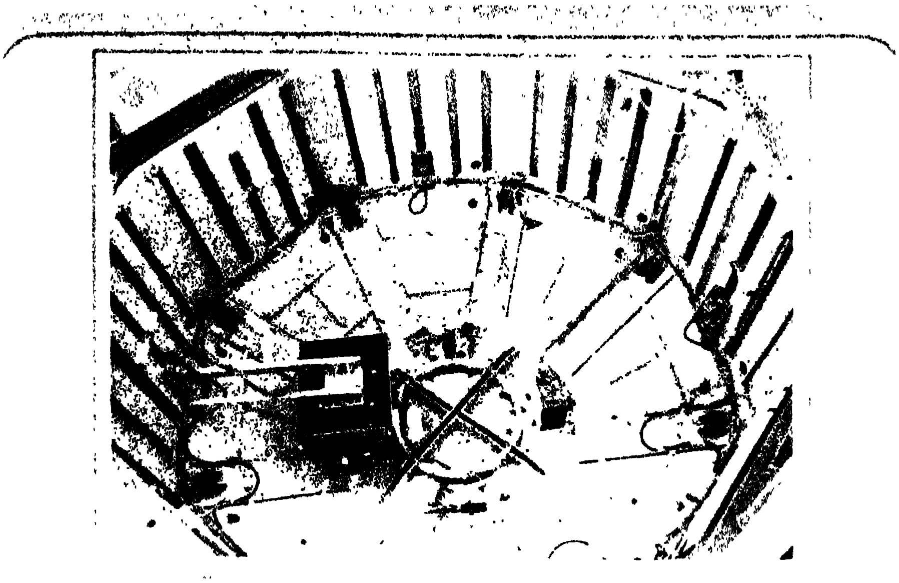
Ferrocement is a thin shell of concrete reinforced with wire mesh, with varying configurations and diameters of wire. It is different from reinforced concrete in that the wires can be bent more easily than the rods used in reinforced concrete. The fineness and dispersion of the steel mesh helps to prevent cracks from propagating. It is more impermeable to water than concrete. Thus, the difference between reinforced concrete and ferrocement (or ferroconcrete) illustrates the distinction between a mixture and a composite. In reinforced concrete, the reinforcing rods take up the tensile load but do not contribute to compressive strength and the concrete takes up the compressive load but does not contribute to tensile strength. In ferrocement, however, the fine wires are uniformly distributed and have large surface area so that the concrete which is weak in tension can transfer the load along the interface to the wire, and because of this *load transfer*, the composite behaves as though it

Composites with operator properties

The composites mainly discussed in this article have additive properties in the sense that the constituent phases contribute proportionally. There is a class of composites where the physical output of one phase operates as the input into the other phase. One example is a composite consisting of a piezomagnetic phase A and a piezoelectric phase B. (Piezoelectricity is the property by which a crystal develops electricity when we stress it, say, by bending it. Conversely, an electric pulse applied to the crystal will change its dimensions. A crystal is piezomagnetic, or magnetostrictive, if it develops a magnetic pulse when stressed or alternately changes dimensions when a magnetic field is applied to it.) In such a composite, the application of a magnetic pulse induces a change in the shape of *A*. Since *A* and *B* are bonded together, *B* is also strained and being piezoelectric consequently develops an electric pulse. Thus, a magnetic pulse is converted into an electric pulse by the composite. The composite is the unidirectionally solidified eutectic of barium titanate ($BaTiO_3$) which is the piezoelectric phase and the mixed nickel-iron oxide ($NiO\text{-}Fe_2O_3$) which is the piezomagnetic phase. Composites with operator properties can have entirely new properties or can give a known conversion but with a higher yield.

Composites for non-structural applications include superconducting cables. It is possible to combine strength with superconductivity when carbon fibres are coated with a superconducting compound. The coated fibres can be wound to form containers for plasma.

For optical applications, sodium fluoride-sodium chloride (NaF-NaCl) eutectics can be solidified unidirectionally so that NaF rods are parallel to the axis of the specimen grown. The composite then has image transmission properties similar to those of fibre optic materials. The spacing between the rods can be controlled by the conditions of solidification. In fact, the solidification in this system was studied under zero-gravity conditions in a space processing experiment and the inter-rod spacing was found to be more uniform compared to the eutectic composites solidified on Earth. The controlled eutectic can then act as a far-infrared transmitting medium for wavelengths longer than the inter-rod distance (typically 6 μm). Other examples of non-structural composites include aligned indium antimonide-nickel antimonide eutectics which are currently in use as magneto-resistive and infrared materials. **S. R. & N. B.**



FRP nutation damper in Aryabhata

An exciting project of design and fabrication of a nutation damper for the first Indian satellite Aryabhata was undertaken jointly by the Indian Space Research Organisation (ISRO) and NAL. Aryabhata is a spinning satellite. A spinning satellite is stable only when it is spun about its axis of maximum moment of inertia. Due to various disturbances, the spin axis wobbles or " nutates ". Whenever this wobble (" nutation angle ") exceeds a specified limit (about 0·1°), the scientific data from the spacecraft become less reliable.

The nutation damper shown in the photograph is a circular *annular* ring with its cross-section in the shape of the letter ' D '. The ring is partially filled with a viscous fluid, say, silicone oil. Although the ring is symmetrical with respect to the spin axis, it is important that its plane does not pass through the centre of gravity of the spacecraft. If the spacecraft is spinning without nutation, the fluid is distributed uniformly inside the ring. When nutation starts and exceeds the specified limit, the liquid tends to flow to one side which leads to the decay in the nutation angle.

The nutation damper makes sure that the nutation angle never exceeds 0·1° at spin rates of 15 rpm or above In order to meet such stringent specifications, the ring was made with considerable precision with respect to the outer and inner surfaces. The ring, 40 cm in diameter, was moulded using an accurately machined mandrel (a shaped rod around which FRP is formed) of a low-melting alloy (Woods metal) After moulding, the ring was immersed in boiling water. The mandrel melted and the molten metal flowed through two small holes The hollow ring was then filled partially with silicone oil and the holes sealed. The nutation damper underwent trials in the laboratory and met all the foreseeable space requirements It is now installed in Aryabhata, and has been performing satisfactorily.

S R & N B

were a homogeneous material and is strong both in tension and compression.

Ferrocement technology is easily acquired and has a number of applications in developing countries, grain silos, storage tanks, boats, etc. If the boat size exceeds 10·5 metres, ferrocement boats are cheaper than those made of FRP, and lighter, too. These are obviously superior to wood which has the problem of warping. In these applications, a layer of FRP can be sprayed onto ferrocement, if necessary. In general, the replacement of wooden structure by composites is a welcome step towards the conservation of forests.

In composites which use cheaper fibres or natural fibres, the cost is controlled by the resin. Hence resins must be developed cheaply and from non-petrochemical sources. In our laboratory, lignin was isolated from coconut shells and the waste from paper industry This lignin was allowed to react with formaldehyde in alkaline medium to give a resin which compares well in its properties with commercially available and more expensive phenolic resins

India entered the age of composites a few years back with the development of the FRP technology for rocket nose cones, radomes, antennas and a variety of components for chemical, electrical and other engineering industries. More recently, a development effort supported by the United Nations Development Programme and the Department of Science and Technology aims at the development of newer fibres and composites in India. Six laboratories are participating in this project. For composites to be more widely used in India, the cost of the fibres and resins must be lowered and non-destructive evaluation procedures must be encouraged so that confidence in these new materials will be generated.

Composites technology has matured to a level where even with high material costs, the cost of composite *structures* is about 15 to 25 per cent less than those made of conventional materials This is because much less material is required since the strength and stiffness are high. Another factor is the low wastage in forming operations, since hand and laser trimming are used The ratio between the amount of raw material purchased and the amount that actually goes into the structure of the completed aeroplane (the buy-to fly ratio) is 10 : 1 for conventional materials, whereas it is only 1·05 : 1 for composites. Today, in a high performance jet plane, about one per cent of the airframe is made of composites but the percentage will increase markedly. A US Government study of Advanced Design Composite Aircraft (ADCA), a nearly all-composite aircraft, showed that the production costs would be lower by 21 per cent and fuel savings would be of the order of 30 per cent. It should be possible in India to construct a light all-composite aircraft as an inter-institutional study project. Even greater impact will be felt in this country when radical changes in our thinking about materials occur as a result of the appreciation of the science of composite materials.

Dr S Ramaseshan heads the Materials Division which he founded at the National Aeronautical Laboratory, Bangalore He has contributed significantly to teaching and research in composite science, crystallography, high-pressure physics, etc He was awarded the S S Bhatnagar Award in 1968 and the Jawaharlal Nehru Fellowship in 1977

Dr N Balasubramanian obtained his PhD in materials science from Columbia University and worked with Allied Chemical and Martin Aerospace in the USA. He was invited by Dr. Ramaseshan to join the NAL in 1972 as head of the Advanced Composites Group His research include composites, dislocation dynamics and high-temperature deformation

Recommend reading. **1.** Dubin, G. (Ed) 1969 *Handbook of Fibreglass Plastics* Van Nostrand, New York **2.** Kelly, A 1972 *Strong Solids*. Clarendon Press, Oxford, UK. **3.** Broutman, L. J and Krock, R (Ed) 1974-76 *Advances in Composite Materials* (6 vols). Academic Press, New York.

NUCLEAR FUSION

Thermonuclear Fusion by Laser

Accelerated ions and electrons and laser beams are now used in experiments to achieve the internal conditions of the Sun in the laboratory or, in other words, thermonuclear fusion (see SCIENCE TODAY, December 1976 and January 1977). The generation of nuclear fusion in tiny pellet targets imploded by laser light and by electron beams (see p 9) has been reported in recent years. But these experiments had not provided definite evidence that thermonuclear burn conditions had indeed been achieved in the core of the pellet Drs. N. M. Ceglio and L. W. Coleman from the Lawrence Livermore Laboratory, University of California, USA, have now claimed explicit demonstration of thermonuclear burn conditions in the compressed centre of a laser imploded pellet in the *Physical Review Letters* (**39,** 20, 4 July 1977).

The earlier claims that fusions had taken place in crushed pellets were based on the recording of sizeable numbers of neutrons with energies characteristic of those given off in the particular fusion reactions under study (deuterium-tritium for the laser experiments and deuterium-deuterium for the electron beam work). The Livermore physicists have, in the report referred to, made measurements on the spatial distribution of alpha particles, another product of the deuterium-tritium reaction.

Using the laboratory's Argus laser-target irradiation facility they conducted two experiments. The standard target used in these experiments was a glass microshell filled with deuterium-tritium gas mixture. In the first, a target of diameter 86 microns was shot with a 2·4 terawatt (1 terawatt = 10^{12} watt) laser beam. In the second, a target of diameter 88 microns was bombarded with a laser power of 3·9 terawatts. The resultant alpha particles were used to reconstruct a high-resolution image of the thermonuclear burn regions at the centres of the imploded targets by a technique called zone-plated-coded imaging (ZPCI) which combined elements of pin-hole photography and holography. Nominal image resolution of the technique was 10 microns. The coded alpha image was recorded on a six-micron thick cellulose nitrate film, a threshold-type ion track detector commonly used in alpha autoradiography.

Approximately 97 per cent of the recorded alpha emission was found to originate within a thermonuclear burn region of diameter roughly one-third that of the original target. The region had an ovoid shape. The major axis of the region in the first experiment was measured as 29 microns and the minor axis as 26 microns. The corresponding figures for the second experiment were 26 and 22 microns. The results demonstrated that the thermonuclear burn occurred within the compressed core and not in the corona of the laser-compressed targets. The burn region had an ion temperature of 5,600 electron volts in the first experiment and 7,000 electron volts in the second. The ion densities were $5·6 \times 10^{21}$ and $1·7 \times 10^{22}$ ions per cubic centimetre, respectively. The thermonuclear burn lasted 36 picoseconds (1 picosecond = 10^{-12} second) in the first experiment and 27 picoseconds in the second.

The alpha imaging results were found consistent with the measured thermonuclear yield. Drs. Ceglio and Coleman state that their "measurements provide an explicit demonstration that the thermonuclear burning produced by laser-driven implosions does indeed occur within a compressed core of the imploded target". They are continuing their imaging studies using the ZPCI technique to image the superthermal X-rays and fast ions emitted from laser imploded targets.

PLANT PHYSIOLOGY

Flower Inhibiting Hormones

An unequivocal demonstration of flower-inhibiting, growth-regulating substances in plants that are also capable of producing the flower promoting hormone, florigen, has been provided by an American and two Soviet plant physiologists. They are A Lang of MSU-ERDA Plant Research Laboratory, Michigan State University, Michigan, USA, and M. Kh Chailakhyan and I. A Frolova of the K. A. Timiryazev Institute of Plant Physiology of the USSR Academy of Sciences, Moscow The results of their cooperative research are reported in the *Proceedings of the US National Academy of Sciences* (**74,** 2412, June 1977).

N sylvestris-**trapezond grafts exposed to long daylight (left) and short daylight (right). Left graft has speeded flowering, right graft no flowering and stunted growth**

Three photoperiodic tobacco plants were used in the study the day-neutral tobacco (*Nicotiana tabacum*) cultivar "Trapezond", the short-day tobacco cultivar, "Maryland Mammoth," and the long-day plant (that flowers in response to long periods of daylight), *Nicotiana silvestris*. Prior to grafting, the Maryland Mammoth and *N silvestris* plants were maintained in their respective non-inductive light periods (light period in which no flower formation occurs). The Mammoth plants were then grafted to some Trapezond plants, the *N silvestris* to others. Part of each grafted Trapezond plant was placed under long days and part under short days and the flowering response of Trapezond was measured.

The researchers found that flower formation in the day-neutral Trapezond was accelerated by graft union with the short-day Mammoth plant when the grafts were exposed to short-daylight periods, and by graft union with the long-day plant *N. silvestris* when they were kept for extended light periods. These results indicated that the flower producing hormone florigen is present in the light-sensitive flowering plants and can be transmitted to the day-neutral Trapezond by grafting, since when the light-sensitive flowering plants were exposed to their ideal lighting conditions the usual light-neutral Trapezond speeded up its flowering. The results support the idea that the florigens of photoperiodic and day-neutral plants are identical or at least fully interchangeable.

On the other hand, when Mammoth-Trapezond grafts were exposed to long-light periods, Trapezond flowering was slightly delayed compared to Trapezond-Trapezond

controls. The flowering of Trapezond was significantly delayed, if not altogether suppressed, when *N. silvestris*-Trapezond grafts were exposed to short periods of light. Trapezond plant growth also became stunted. These results strongly indicate that the long-day *N. silvestris* possesses, under short-day (less than ideal) lighting conditions, potential flower-inhibiting and growth-regulating chemicals that can also be transmitted to a day-neutral partner. Similar flower-inhibiting chemicals also appear to be present, though to a smaller extent, in the short-day plant Maryland Mammoth under long-day conditions. What now remains to be done is to extract and chemically identify both these inhibitors and florigen.

'behind the teacher's back'. At the time the studies were made, their oral education had not produced any significant learning; they had acquired few, if any, spoken language items that they could regularly use in their daily activities.

The children were visited in their homes by two experimenters for one to two hours at intervals of approximately one and a half to two months. They played with a standard set of toys during the interview when the informal interactions of mother, experimenter, child and toys were videotaped. The communicative gestures observed were broken down into single items analogous to words or signs and into multi-sign units analogous to phrases. Each of the deaf subjects was found to have developed a structured communication system that incorporated properties found in all child languages.

The children, in fact, made use of much more extensive repertories of signs than their mothers. The gestures fell into two main categories, corresponding roughly to signs for pointing to a place, person or object (" there " or " this ") and motor-iconic signs representing actions. From these signs, the children could construct phrases of short sentences such as " you give this to me ". For example, one child opened his hand with his palm facing upward and then followed this " give " sign with a point towards his chest, to request that an object be given (act) to him (recipient). Some of the children produced their signs for the patient, recipient, and act semantic elements in consistent positions of their two-sign phrases. Specifically the children tended to produce more phrases with patient-act, patient-recipient and act-recipient orders.

Evidence was also obtained that indeed it was the children who first produced the signs and that each of the children could invent characterising signs of his own. They also produced multi-sign phrases that conveyed semantic relations earlier than their mothers. The development of the sign language in these children appeared quite spontaneous. Their behaviour, too, was in striking contrast to chimpanzees, reared in human families with a view to teaching them language. The apes, no matter how lovingly they are brought up as human babies, show no spontaneous language development. On the other hand, the Chicago psychologists state that " even under difficult circumstances, the human child reveals a natural inclination to develop a structured communication system ".

K. A. NEELAKANTAN

INDUSTRIAL MICROBIOLOGY

Improving the Yield of Antibiotics

The technique of cell fusion may help in improving the yields of valuable commercial medical products. This has been demonstrated by David A. Hopwood and his colleagues at the John Innes Institute, Norwich, UK, together with Stanley N. Cohen of the Department of Medicine, Stanford University School of Medicine, California, USA, in a letter to *Nature* (**268,** 171, 14 July 1977). They have with the technique forced different strains of *Streptomyces* to interchange their genes efficiently, and thus potentially made the task of the industrial microbiologist easier. The latter now needs to scan fewer numbers of cells to find the upstart that he is looking for in the quest for improved antibiotic yields.

The *Streptomyces* family of bacteria is cultured commercially for the production of over 60 per cent of known antibiotics, including streptomycin and the tetracyclines and an enzyme (glucose isomerase) that is vital to the cane sugar industry. Members of the related genera *Nocardia* and *Micromonospora* produce some further valuable antibiotics such as rifamycins and gentamicins. The standard technique hitherto used for obtaining better-yielding strains of *Streptomyces* has been to induce genetic mutations in the cell. Another approach has been to look at the progeny of the very rare sexual matings in which the genes of both parents get mixed up and reassorted. In normal circumstances, however, gene exchange through sexual reproduction occurs only about once in a million and the identification of the recombinants requires time-consuming and complex procedures.

The cell fusion technique involves initially stripping the outer layers of the bacterial cell walls. The semi-naked cells (protoplasts) are then made to fuse with the help of polyethylene glycol (PEG). This is followed automatically by the regeneration of normal forms of *Streptomyces*. Five species were used in the experiments, namely, *S. coelicolor*, *S. parvulus*, *S. lividans*, *S. griseus* and *S. acrimycini*. On analysing the cells it was found that at least one in a hundred and up to one in 20 of the offspring are genetically distinguishable from the parents due to the improved frequency of exchange of genes between the two parent chromosomes brought together by forced fusion. Hopwood and his colleagues claim that the recombination frequencies achieved by the technique are very high.

It would naturally be easier for a microbiologist to select the desired characteristics he wants when as many as one-twentieth of the cells are genetically novel, rather than search a million cells for one with promise of improved antibiotic yields.

PSYCHOLOGY

Language Development in Deaf Children

A strong support for the hypothesis that there is an inherited tendency in humans to develop a language of their own - a sort of structured communication system that has many of the properties of natural spoken language - has been provided by Susan Goldin Meadow of the Department of Education, University of Chicago, Chicago, Illinois, USA, in collaboration with Heidi Feldman of the School of Medicine, University of California, San Diego, USA, in a report to *Science* (**197,** 401, 22 July 1977). Their conclusions are based on a study of six deaf children between the ages of one and a half and four years and born of parents normal in hearing.

The parents have decided against exposing these children to the standard manual sign language in order to concentrate on oral education, consisting of lip reading and speech production with no audio feedback. Such children have been observed to spontaneously gesture to one another

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MARK COOK

How long—and when—we look others " in the eye " is one of the main signals in nonverbal communication

Looking at others, and being looked at by them, is of central importance in social behaviour. We use our eyes to study the behaviour and appearance of others, and we look particularly in the region of their eyes. This is familiar and obvious and has often been described by novelists and poets. Psychologists, however, failed to take any interest in these phenomena until very recently, and almost no research was done until the early 1960s, when G. Nielsen, in an observational study at Harvard, carried out the first research on gaze in social behaviour [*Studies in Self Confrontation*, 1962]. At about the same time Ralph Exline, at the University of Delaware, started a long series of studies, using standard experimental designs, with amount of gaze first as the dependent and later as the independent variable. In Britain, at Oxford University, Adam Kendon started his ethological studies on the sequence of glances in conversation and on the linkage of verbal and bodily signals. A research group was started at Oxford by Michael Argyle, taking in Kendon and E. R. F W. Crossman, and, later, I joined them.

From the mid-sixties, the volume of research on gaze expanded rapidly, and in the decade 1965 to 1975, a great deal was discovered on the topic. This research (described and evaluated in a recent monograph, Argyle, M. and Cook, M. 1976 *Gaze and Mutual Gaze*. Cambridge Univ. Press) has led into a new field in social psychology - *nonverbal communication*. Previously, models of social interaction had been largely abstract, and little attention had been paid to the mechanics of communicating with others and of forming and creating impressions. Gaze is one of the main nonverbal signals, together with facial expression, posture, proximity and tone of voice. A more general review of the whole field of nonverbal communication is given by Argyle [1975 *Bodily Communication*, Methuen].

Studying gaze

Gaze is defined as looking at another person in or between the eyes, or, more generally, in the upper half of the face. Mutual gaze, as the words suggest, implies that " eye-contact " is made with another person. Most research has relied on human observers to collect data. A typical arrangement for studying gaze in a conversation between two people is to position the observer out of sight behind a one-way mirror, so that he is as nearly as possible looking over the shoulder of one of the subjects. When the other subject looks at the first, he is also looking toward the observer, who records the fact (Fig. 1a, p. 24).

Obviously, the arrangements get more complicated if the gaze of both subjects is to be recorded. One-way screens have been superseded by closed-circuit TV (Fig. 1b) and videotape-recordings since they have become commercially available, and many ingenious — and deceitful — ways of concealing the cameras have been devised; my favourite is to pretend that the camera is not in use by prominently displaying an unplugged mains lead. The subjects have to be deceived about the purpose of the experiment, as they would be self-conscious and probably change their behaviour if they knew what was being studied. Some research has been done outside the laboratory, notably studies on " visual threat " carried out at road junctions with traffic lights [Ellsworth, P. C. *et al* 1972 The stare as a stimulus to flight in human subjects: A series of field experiments. *J. Pers. Soc. Psych.* **21**, 302-11].

In early research, the observer recorded gaze with a cumulative stopwatch, which soon gave way to multichannel pen-recorders and to electronic event recorders. The observer now presses keys when the subject or subjects are looking and releases them when the subject averts his gaze; additional channels are usually provided to record the fact that the subjects are talking. Thus, in an experiment recording the gaze of two subjects, there would be a four-channel record — two channels for gaze and two for speech. Fig. 1c is a sample from a record of this sort. A large number of measures could be extracted from such a record, but most researchers have been content to use simple measures of the percentage of a given period of time that gaze or mutual gaze occupies. To study mutual gaze, the experimenter must either measure both subjects' gaze or employ confederates — people who pretend to be naive subjects but who are part of the experiment and whose behaviour is programmed beforehand. Of course, if the confederate looks at the " real " subject continuously, then any gaze by the subject must be mutual gaze.

The " over-the-shoulder " method of recording strikes many people as crude and likely to be unreliable, even when video recordings are used. The method, after all, relies on the human observer's reaction time, which averages around ¼ sec, with a considerable standard deviation, and also on the observer's ability to correct for the fact that he is not actually the target of the other's gaze, not to mention his

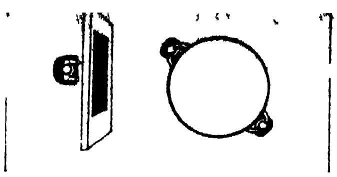


Fig. 1a Earlier "over-the-shoulder" gaze studies were done through one-way mirrors

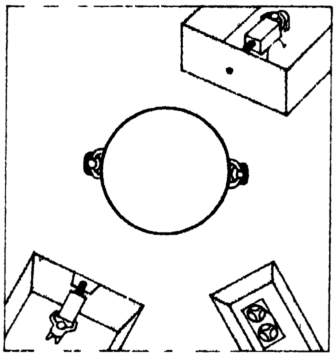


Fig. 1b More advanced methods use closed circuit TVs and voice recorders

ability to maintain concentration over long periods. Nevertheless the technique is surprisingly reliable: retest reliabilities of 0 90 or better are reported, which is good by the standards of psychological research. Evidence of the validity of the method is provided by a study by D. R. Rutter and G. M Stephenson, who compared a record made by an observer with a record by the looker himself, who pressed a key whenever he looked the other subject in the eye. The two records achieved 96 per cent agreement on amount of looking during a certain period of time

The researcher who wants greater precision has a variety of techniques, described by A. Cowey [1963 *Quart. J Exp. Psych.* **15,** 81–90], to choose from, but all have serious disadvantages for studying social behaviour, because they either use equipment mounted on the head or require the head to be clamped in place. The most promising is the eye-mark camera, devised by N H. Mackworth, in which a light reflected from the eyeball is mixed into an image of the subject's visual field and, with careful calibration, can be made to indicate the wearer's fixation point to within one degree of field, and to the nearest 1/50 sec While this equipment is cumbersome for social-interaction research — it obscures the wearer's face almost completely — it is invaluable for studying the fine detail of gaze patterns

Table 1 gives some typical findings from a study by Argyle and Ingham, illustrating points first made by Kendon. On average, people look at each other about 60 per cent of the time, but the range of individual differences is considerable Quite a few people look continuously, while others look as little as 8 per cent of the time People look more while listening than while talking, it being usual to look at someone more or less continuously while he is speaking, whereas gaze while speaking usually takes the form of frequent short glances, occupying less than half the available time Mutual gaze typically takes up a third of the time, with individual eye-contacts being fairly short. The brevity of mutual gaze and personal experience both suggest eye-contact is hard to maintain, and is perhaps avoided.

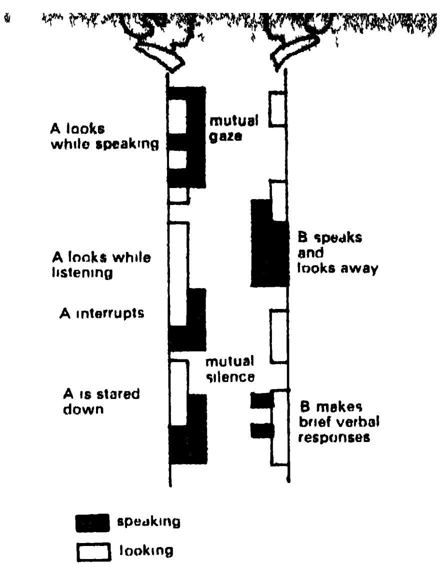


Fig 1c New techniques for studying gaze permit the observer to record both speech and gaze patterns of two subjects (from *Social Interaction* by M. Argyle, 1969)

The Strongman-Champness formula — % expected eye-contact = % of time *A* looks × % of time *B* looks — was devised to calculate how much mutual gaze would result by chance [Strongman, K T. and Champness, B. G 1968 Dominance hierarchies and conflict in eye contact. *Acta. Psych.* **28,** 376–86]. The value obtained by the formula can be compared with the observed value, to see if *A* and *B* are deliberately avoiding each other's gaze or are purposely seeking it out In Argyle and Ingham's data, observed value was less than expected value, showing that each subject did seem to be avoiding the other's eye somewhat.

Table 1 also shows that women look more, particularly when talking to other women· this is a very reliable finding and has been reported on both sides of the Atlantic, although no convincing explanation has been offered for it. Some personality differences have been reported — in particular that extroverts look more often than introverts. Argyle and his colleagues found that a high proportion of patients referred for inability to get on with others had unusual gaze patterns: 34 per cent looked an abnormally high proportion of the time and conveyed an impression of staring, whereas 18 per cent looked an abnormally low proportion of the time.

It is often said that schizophrenics do not look at people, and for chronic patients it may be true, but newly admitted patients, while looking less than normal on average, still fall well within the normal range. Evidently avoidance of gaze in chronic patients is a symptom of institutionalisation rather than schizophrenia. Rather similar findings have been reported for depressive patients.

Avoidance of gaze is, however, specific to autism or childhood schizophrenia and is used as a diagnostic cue Autistic children look at people very rarely – 4 per cent of the time in one study and in very short glances. They go out of their way to avoid another's eye, putting a hat over their own eyes, looking through their fingers, or simply turning away. One theory argues that autistic children are chronically overaroused and thus avoid any contact with others, particularly the most significant stimulus of all — a human face looking at them.

Research using an eye-mark camera shows that " looking someone in the eye " is in fact not quite literally that It has long been known that it is impossible to look at precisely the same point for any length of time without the visual field going blank, because the eye needs change for stimulation of the visual nerves. What seems — both to the looker and the looked-at — to be a steady gaze is

Fig. 2 During 10 seconds of apparently steady gaze, the eye of the listener actually fixes on many different points — 18 in the example shown here — in the face of the person he is listening to

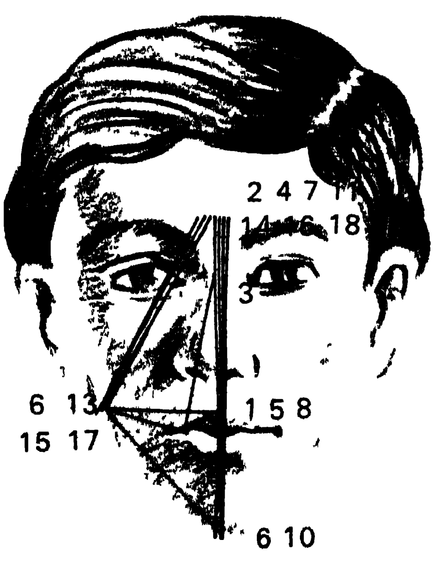


TABLE 1. RESULTS OF A TYPICAL GAZE-DIRECTION EXPERIMENT

	Male talking to male	*Female talking to female*	*Male talking to female*	*Female talking to male*	*All subjects*
Per cent of time spent looking	56	66	66	54	61
Per cent of listening time spent looking	74	78	76	69	75
Per cent of speaking time spent looking	31	48	52	36	41
Per cent of time spent in mutual gaze	23	38	31·5	31·5	31
Average length of gaze, in seconds	2·5	3·1	3·6	3·0	3·0
Average length of mutual gaze, in seconds	0·9	1·4	1·3	1·3	1·2

[Data collected from Oxford University Students. Argyle, M. & Ingham, R. 1972 Gaze, mutual gaze and proximity. *Semiotica*, 6, 32-49].

actually a series of rapid, repeated scans of the face. Fig. 2 illustrates a typical 10 seconds of eye-contact — in reality a sequence of 18 fixations mostly on the mouth and the bridge of the nose. Because not all eye-contact is focused directly at or between the eyes, I. Vine has suggested that *face-reaction* would be a more appropriate term [1971 *Brit. J. Soc. Clin. Psych.*, **10,** 320-31].

Although each individual has his own characteristic gaze pattern that remains more or less consistent from one encounter to another, these patterns are influenced by a variety of outside factors — whom the person is with, what sort of meeting it is, and what the people think of each other. In particular, the way one person looks at another says a lot about his opinion of the other, about his " interpersonal attitudes ", as social psychologists tend to put it.

An experiment by Exline illustrates both the findings obtained and the methods used. The subjects — college students — came for an experiment ostensibly on concept formation; half-way through the proceedings, the experimenter told the subject his performance was very poor or very creditable, or he expressed no opinion either way. The proportion of the time the subjects looked at the experimenter before and after this revelation was recorded, and it was found that the " very poor performers " took a strong dislike to the experimenter, and all of them, without a single exception, looked less at him subsequently.

Other research has relied on the fact that even in short experimental encounters, subjects form definite preferences for each other, without any intervention by the experimenter. Typically, three subjects, or one subject and two confederates, are studied, and the amount of time one subject looks at the other is compared with his preferences. In one study the amount of mutual gaze showed a low but significant correlation of 0·40 with liking for the other. This may seem obvious to some people, but, in my experience, it comes as a revelation to quite a few others, who suddenly realise just what the mysterious " something " is that tells them they are not getting on with someone.

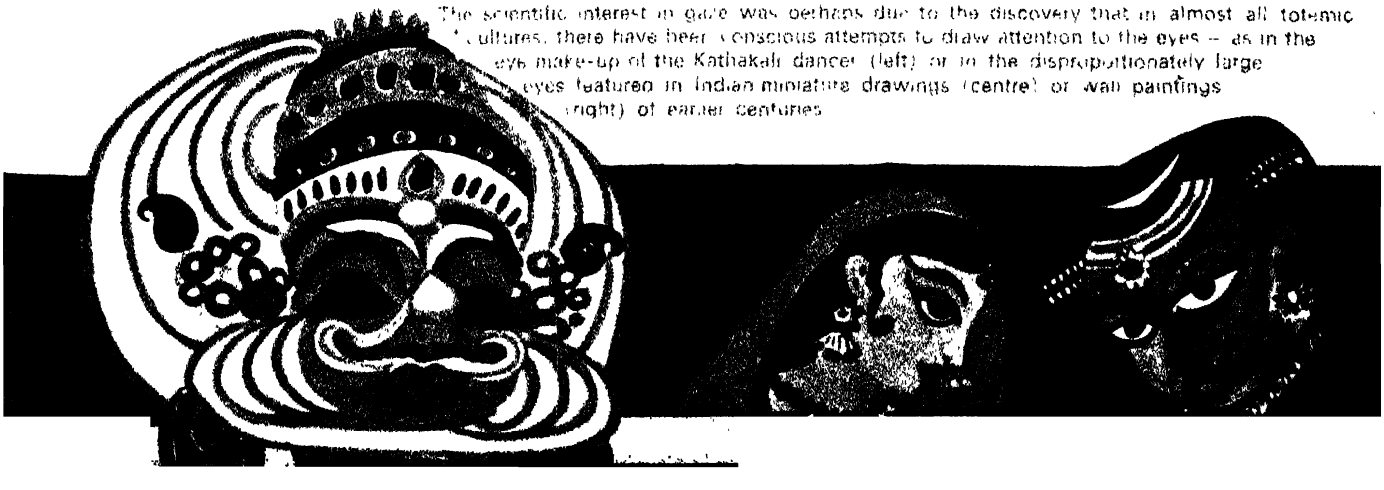
Positive dislike or hostility can also be indicated by gaze, but not always in the same way. Sometimes people look; sometimes they look away. An example of the former is the " hate stare " directed at Negroes by White people in the South of the United States; in fact, the same thing happens elsewhere but is not obvious or frequent enough to be named. The hate stare is a deliberate breaking of the usual norm of what E. Goffman calls *civil inattention* to strangers in public places. Hostility can also be expressed by looking away when the usual thing would be to look at the other — cutting or snubbing.

In animals, too, gaze plays a part in establishing and maintaining social relations. It has been observed that rats and birds adopt postures that have the effect of reducing the visibility of other animals — such as turning the head or body away, tossing the head, shutting the eyes, or assuming sleep postures. These cut-off postures, as they are called, which are adopted during aggressive encounters as well as in courtship, have the effect of reducing aggression or the urge to flight. They also act as appeasement signals to other animals, who are then

The " look " of love

Some literary and anthropological references confirm that gaze is very important in courtship. Casanova describes how women in 18th century Madrid relied on glances as an invitation, because the repressive moral atmosphere of the day prevented any other approach. Stendhal anticipated modern ideas on nonverbal communication when he noted that women gave invitations by gaze because they could always later repudiate the contract, as it could not be quoted. Margaret Mead observed that courtship on Bali proceeded entirely by the exchange of glances. The work of E. H. Hess showed that the pupils of the eye dilate when a person is sexually excited by what he or she sees, and also that photographs of women in which the pupils have been enlarged by retouching are preferred by men [1965 *Scientific American*, **212,** 46-54].

M. C.



The scientific interest in gaze was perhaps due to the discovery that in almost all totemic cultures, there have been conscious attempts to draw attention to the eyes — as in the eye make-up of the Kathakali dancer (left) or in the disproportionately large eyes featured in Indian miniature drawings (centre) or wall paintings (right) of earlier centuries less likely to attack. In primate groups, there is often a visual attention structure, in which attention is directed upward to more dominant animals. The dominant animal's confident postures include a stare at the other animal, as well as a slight frown; the submissive animal will avert gaze in any encounter, which reduces the likelihood of attack. A striking illustration of this function of gaze was given by Exline [1971 *Nebraska Symposium on Motivation*, pp. 163-206]. A human experimenter stared at a caged rhesus monkey, which reacted on half the occasions by launching an attack. If, however, the experimenter looked away, the likelihood of an attack was halved.

It is always tempting to extrapolate this sort of finding too readily to humans, and frequent press reports of fights in bars, in the streets, or at football matches being started by one youth staring at another add to the temptation. The novelist Kingsley Amis referred to " the unspoken code which prohibits the eye from resting on a stranger for more than two seconds". However, the difficulty of measuring dominance patterns in human groups, or even establishing their existence, makes such extrapolation dubious. Strongman and Champness did find that if *A* can stare down *B*, and *B* can stare down *C*, it follows, with few or no exceptions, that *A* can stare down *C*, but the study had no other measure of dominance.

Darwin in 1872 noted that people who are ashamed or embarrassed look down [*The Expression of Emotion in Man and Animals*], and recently an ingenious experiment by Exline proved this observation experimentally and took it a little farther. In the experiment, subjects became implicated in cheating with a confederate and were then questioned by the experimenter. Their gaze was measured before the cheating, during the encounter with the experimenter but before he accused them, and after the accusation. Before the experiment, the subjects were classified as high or low on a questionnaire measure of " Machiavellian " personality. Subjects with low Machiavellian personalities looked away from the experimenter after he had accused them of cheating, whereas the high Machiavellian subjects looked as much as they had done before they had cheated. Evidently there are some people who can control their nonverbal behaviour so as to convey a desired impression, and who are quite prepared to do so.

Another well-known experiment [Milgram, S. 1974 *Obedience to Authority*. Tavistock] involved instructing subjects to give confederates strong electric shocks — never received in reality — and it was observed that people turned away when doing this, evidently unable to look the victim in the eye. (Social psychologists have become more sensitive to the issue of experimental ethics since these two studies were done!) Most people have at one time or another found themselves unable to look someone in the eye, and know how powerful the effect can be; unfortunately psychologists have not been able to improve much on Darwin's suggestion that people are like ostriches — thinking that if they can't see someone, the someone can't see them.

evil eye and all that!

Some philosophers and philosophical psychologists have attributed great mystical significance to the experience of being looked at; for example, Merleau-Ponty speaks of people being " stripped of existence " or being " transformed into an object " [1962 *Phenomenology of Perception*, Routledge and Kegan Paul]. Occasionally, psychiatric patients suffer from delusions about being looked at, supposing that they will be turned to stone or suffer some similar fate. These irrational ideas about gaze have been widespread in some cultures, particularly those that believe in the "evil eye". The ability to put a curse on people, crops, or animals was less often ascribed to men than to women, who were either born with it or got it by making a pact with the devil [Gifford, E. S. 1958 *The Evil Eye*. Macmillan]. Of course most people find it unpleasant and threatening to be stared at by a stranger, and thus, it is perhaps not surprising that people in primitive societies invest the threat with magical significance, although this does not explain why only a few people in any group are supposed to have the evil eye.

Another explanation for the fear of being stared at relies on *innate releasing mechanisms*. It is known, for example, that eye-spot patterns are frightening or threatening to some species of birds; perhaps, the same is true for humans, and perhaps, the belief in the evil eye is a remnant of this. However, the literature on the evil eye does not confirm the theory. If the fear stems from an innate releaser, then people whose eyes conformed to the innate releaser — that is, whose eyes were prominent and symmetrical — would be thought to have the "gift", but in fact the " eye " is most readily attributed to people with only one eye, or with a squint or drooping eyelids, or with eyes of different colours or unusual colours for the racial group.

The belief is also related to the idea that vision works by rays that emanate from the eyes; it has been supposed, for example, that when a witch looks at a mirror she leaves a thin poisonous film on it. This death-ray view of gaze lingers on in the belief, held by three-quarters of an American college sample, that you can definitely tell when someone behind your back is looking at you. Magical significance has also on occasion been attributed to *not* looking at people: the Mende of Sierra Leone, who believe that the dead can reappear as human beings and can be recognised because they never look one in the face, are very suspicious of people who avert gaze during conversation.

M. C.

How long do people look?

The amount of time one person looks another in the eye gives some clue about how he actually feels about the other: but how is the look interpreted? The real and attributed meanings may be quite different. For example, all sorts of inferences are based on the mere appearance of someone's face, most of which are quite false. Conversely, there are changes in facial expressions — " micromomentary " expressions — so fast that they can be detected only by frame-by-frame analysis, which are probably excellent cues to repressed dislike but which have no communicative significance, because they cannot be seen by the human observer.

In fact, some people do not seem to notice whether or not others look them in the eye — perhaps the very people who do not look themselves. Several studies have found that around half the sample would notice or comment spontaneously on someone else's gaze patterns when they were fairly unusual, but when it came to estimating the amount of time someone was looking, people were very unreliable witnesses. If, however, people do notice when others are looking at them, they will draw some inference from it, and the first and simplest conclusion they reach is that the person is interested in them. If someone is looked at by a stranger or by someone he is not interacting with, he expects something to happen or an "interaction" to start. Indeed, in any situation, " catching someone's eye " makes it almost obligatory to start an interaction: hence waiters and chairmen develop the ability to avoid eye-contact.

A series of studies have shown that, on the whole, the more one person looks at another, the more the other person will feel that he is liked. The distribution of the looking is important, according to one study, which found that subjects preferred others who gave long glances, but evaluated less favourably those who looked frequently and in short glances. A study by Argyle [1974 *Eur. J. Soc. Psych.*, **4,** 125–36] suggests that there is not a simple linear function between looking and favourable evaluation: continuous gaze was less well received than the normal pattern of looking approximately three-quarters of the time. Perhaps looking all the time is seen as too intimate or as a form of ingratiation, at least in a fairly formal encounter such as a psychology experiment.

A number of studies have found that people who look more are seen as more truthful or credible, which is a valid inference, since Exline and his co-workers have shown that people not telling the truth usually look less. However, the commonest inference people draw when someone does not look them in the eye is that they are nervous and lack self-confidence. In another study, people who looked only 15 per cent of the time were described as " defensive, submissive, sensitive, cautious and immature " [Kleek, R. E. and Nuessle, W. 1968 *Brit. J. Soc. Clin. Psych.*, **7,** 241–46]. This is interesting because there is no evidence that anxious people in reality look less or that stress makes people look away. For once, the actual and the supposed significance of looking someone in the eye do not coincide.

Looking someone in the eye is of course only seen as friendly if the looker is talking to the person or knows him. If the target of the gaze is a complete stranger, he will interpret the look quite differently. An unpublished study by Thayer found that people stared at in a college library showed signs of unease, sometimes protested, and in few cases got up and left the room. Ellsworth and her colleagues employed confederates who stared at motorists waiting at red traffic lights, and discovered that this made the motorists drive off more quickly. In other places, staring at someone might well, as we have noted, lead to a fight or at least the threat of one. There is no need to invoke instinct or man's simian ancestry to explain this: years of experience have taught people that being looked at is the start of something — precisely what, will depend on the circumstances, but if the looker is a perfect stranger, the something may well be unpleasant.

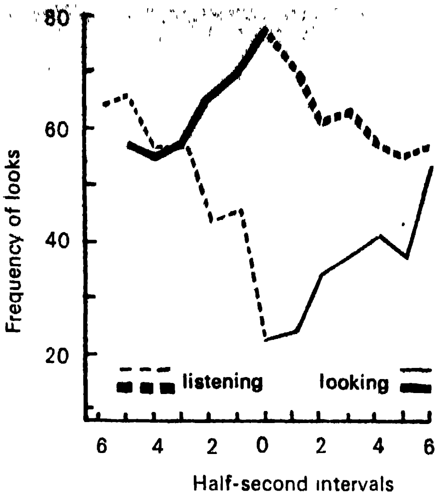


Fig. 3 Patterns of gaze show that people usually look away at the beginning of long utterances but that they generally look at the person they are speaking to at the end of the utterance. The thick line represents the gaze pattern of those who stop speaking and start listening at O; the thin line, those who stop listening and start speaking (from A. Kendon in *Acta. Psych.*, 26, 1-47)

The amount of time a person looks is also affected by what he is talking about. Exline and his co-workers studied the effects of an embarrassing topic on how long a person looks. Subjects were interviewed either about a very personal topic or about a neutral topic like books or films. Those who were asked personal questions looked less while speaking and listening. A further study by Exline and Winters varied the cognitive difficulty of the questions asked by the interviewer and found that the subjects looked only half as much while talking (and thinking) about the most difficult topic.

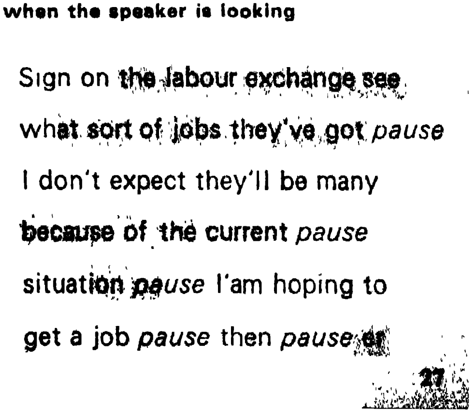
When do people look?

A series of studies by P. Bakan [1971 *Psych. Today*, **4,** 64–67] and others have shown that people look away when asked a question and that they tend to be fairly consistent in looking to one side or the other. The choice of looking left or right is not randomly or trivially determined, as one might suppose, but is related to important aspects of personality and intelligence. Right-shifters are more likely to study science or mathematics, while left-shifters are more likely to study classics or humanities. Left-shifters also have more vivid visual imagery. The right-left shift difference is thought to be related to cerebral dominance, since the right hemisphere is usually dominant for spatial concepts, as well as for musical, metaphoric, and analogical thought processes, while the left is dominant for verbal and rational matters. The precise reason why people should look away in one direction or the other is uncertain.

Kendon remarked on the fact that people often look away whenever they start speaking, not just when they are answering questions, and also noted that the person finishing an utterance does the opposite, looking steadily at the person who is about to start speaking (Fig. 3). He suggested that looking up at the end of an utterance is a signal to the other that the person is about to stop speaking; when people neglected to give the signal there was an embarrassed silence. The reason people look away when starting to speak is less clear. Kendon originally thought it, too, was a signal, indicating readiness to take over from the previous speaker, but this is uncertain.

Kendon also observed that people look away when hesitating, and more recent work with an eye-mark camera has underlined this very clearly, as the data in Fig. 4 show. For this speaker, as for others, a hesitation is an almost certain cue to a sideways glance. The eye-mark camera, which records where the subject is looking when not looking the other in the eye, shows clearly that he is not looking at anything in particular when looking away during a hesitation. Some glances are to the left or right in a horizontal plane of the type Bakan and others have studied, but other

Fig. 4 This extract of speech illustrates the relation between aversion of gaze and hesitation. The grey bars indicate when the speaker is looking



Sign on the labour exchange see
what sort of jobs they've got *pause*
I don't expect they'll be many
because of the current *pause*
situation *pause* I'am hoping to
get a job *pause* then *pause* at

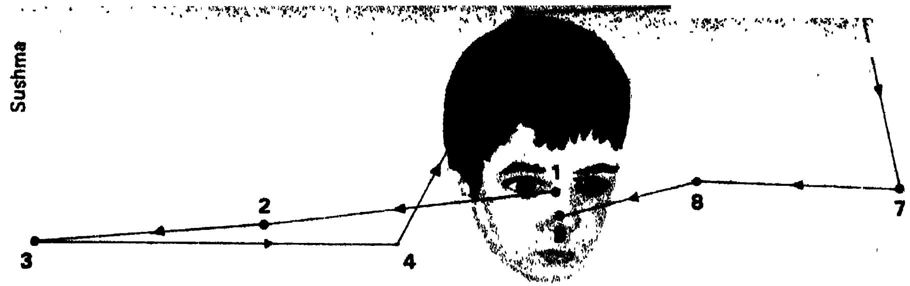


Fig. 5 Many glances away during speech are more complex than simply looking in one direction or another. Here the speaker looks first to the left, then over the other person's head and to the right, before returning his gaze to the other's face

glances are more complex, moving to one side of the other's face and then fixating a series of points in an arc over his head, which reaches the other side before returning to his face (Fig. 5). All the points fixated are in the middle of a featureless white wall; wondering what the person is looking at reminds one of the old schoolroom comments about not finding the answer written on the wall. Many of the glances away are very fleeting, most lasting only a second or so, and some are detectable only in a frame-by-frame analysis, which goes against Kendon's original theory that the speaker looks away during hesitation to avoid giving the false impression that he has finished, which might result from a combination of silence and looking the other in the eye.

The theory put forward by Exline and L. C. Winters seems to account best for the data from the eye-mark camera: they suggested that an individual looks away when uncertain to avoid the distracting effects of seeing the person he is talking to [1966 in *Affect, Cognition and Personality*. Tavistock]. The fact that glances away during hesitation were directed at a featureless wall is consistent with this hypothesis. It is possible that the looking away at the beginning of an utterance described by Kendon is not specific to starting speaking as such but simply occurs because the beginning of an utterance is a very likely place for a hesitation, while formulating what is to be said. Certainly one or two experiments have failed to find aversion of gaze at the beginning of utterances, perhaps because the topic of conversation was a very easy one.

Gaze direction has been studied largely for its own interest, but the research does have some practical applications. Armed with a detailed knowledge of when people look and why, it is possible to modify the behaviour of those who have failed to learn the art of conversation or who find it difficult to look at other people. Argyle and his colleagues have had some success in improving the social skill of selected neurotic patients. Interviews with the patients, filmed before treatment has begun, are used to devise a programme of training to correct defects, which may include not looking and thereby creating an impression of disinterest and hostility, looking too much and thus appearing too keen or otherwise unsettling other people, or looking at the wrong time and upsetting the smooth flow of the conversation. The author is engaged in a similar project to assess changes in the social behaviour of adult mental defectives, many of whom also fail to look at the appropriate time and place in conversation.

A knowledge of the functions of gaze direction in interaction also leads to some predictions about what will happen when people cannot look at each other. The principal focus of interest here is the possible merits of videophones against conventional telephones. Although it might be predicted that videophones would enable people to assess each other's reactions, establish friendly relations more quickly, and avoid interrupting, there is not much evidence of any change in the interaction when people cannot see each other. In fact, it seems that people adapt very readily and learn to use other ways of communicating.

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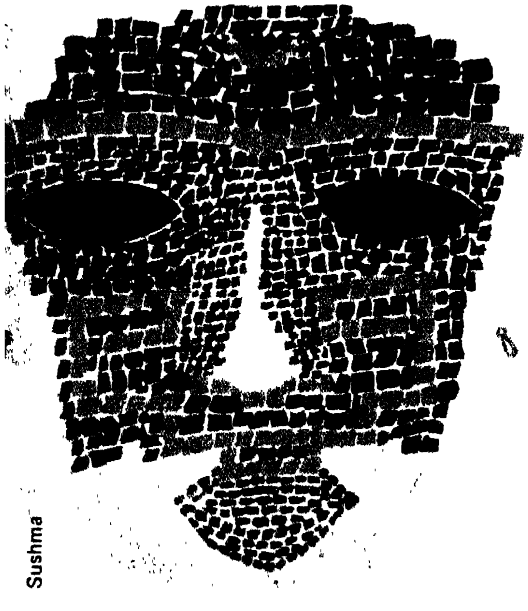
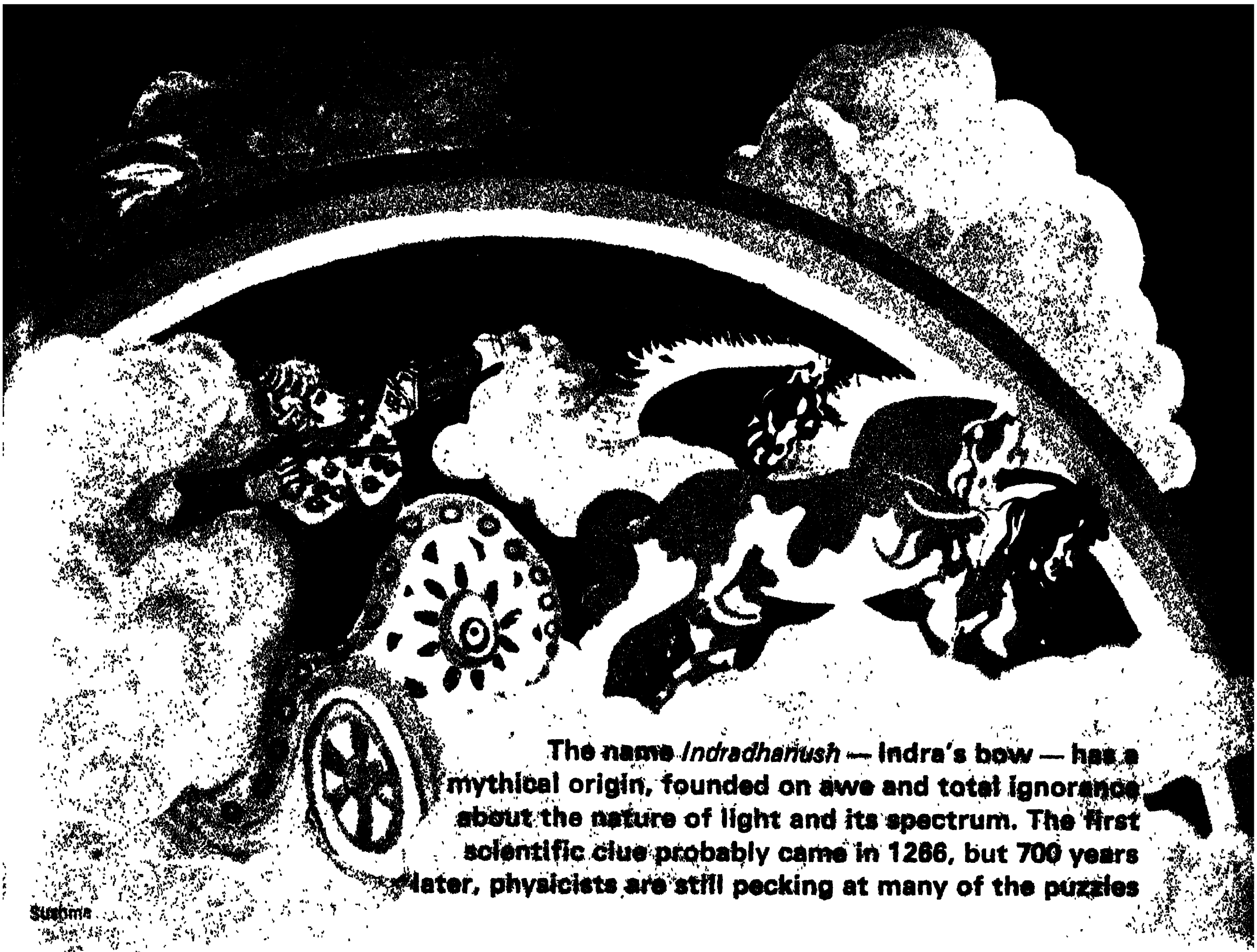


A mask is merely a facial costume of identity, as is the paint on a clown's face— both silent on character and feeling, if there are no eyes to speak. . .



Sushma

The name *Indradhanush* — Indra's bow — has a mythical origin, founded on awe and total ignorance about the nature of light and its spectrum. The first scientific clue probably came in 1266, but 700 years later, physicists are still pecking at many of the puzzles

WHAT MAKES A RAINBOW?

VIVEK MONTEIRO

"... rainbows differ among themselves, as one tree from another, and besides, some of their most interesting features are not even mentioned — and naturally so, for the 'explanations' generally given of the rainbow may well be said to explain beautifully that which does not occur, and to leave unexplained that which does."

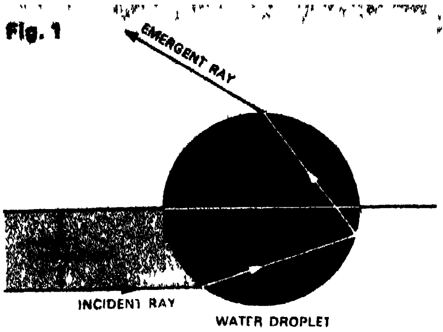
[W. J. Humphreys, *Physics of the Air*]

Isaac Newton is often credited with having given the correct explanation for the colours of a rainbow. According to the typical account, Newton passed white light through a prism, and caught the refracted rays on a screen producing the characteristic spectrum. White light is made up of seven colours, VIBGYOR, . . . and hence the rainbow.

But raindrops do not fall in the shapes of Newton's prisms. Moreover, careful observation of different rainbows shows that no two rainbows have precisely the same colours. In any case, the colours of a rainbow are never as pure as those produced by a prism. Then, in Newton's experiment, the prism was situated *between* the light source and the observer's eyes, so that the rays of the light source and the 'coloured spectrum' appear from the same side of the observer. But in naturally occurring rainbows, the Sun and the rainbow appear on opposite sides of the viewer, and rainbows are never seen in the east at dawn or in the west at sunset. Finally, rainbow-like colours are seen in many circumstances, where there are neither prisms nor spherical drops as, for example, in oil slicks on the surface of a puddle. For all the above reasons and many more, it will be appreciated that the elementary textbook 'explanation' attributed to Newton cannot be considered as satisfactory. It does not even explain many characteristics of the common rainbow, let alone the not infrequent phenomenon of the double rainbow, where a secondary, fainter rainbow is seen higher in the sky, with the colour sequence reversed. Newton's experiment was certainly not the last word on the subject. It was not even the first.

The history of correct or near-correct explanations of the rainbow goes back at least seven centuries to the year 1266. In that year Roger Bacon measured the angle between the rays of the primary bow and the direct rays of the Sun showing this to be invariably about 42°. (The rainbow having a finite width, it is not possible to define this angle precisely.) Much earlier than this, Aristotle himself had conjectured that rainbows might be caused by some kind of unusual reflection of the Sun off the raindrops. But like much of his other conjectures on the natural world, this must be considered as an armchair speculation, quite worthless to the development of the science. Some 40 years after Bacon, in 1304, came the first leap forward, the fruit of the brilliant work of a German monk — Theodoric of Freiburg. Theodoric studied the passage of light rays through a single water drop (he used a spherical flask filled with water) and showed that the rainbow occurs in rays that suffer

Fig. 1



one internal reflection (Fig. 1). Thus, each raindrop produced a rainbow. Theodoric's work — the process of abstraction required to reduce the problem to the study of a single spherical drop — is a theoretical and experimental achievement of the first order. Remember, this was in 1304, some three centuries before Galileo (1564–1642) who is usually credited with having founded the scientific method.

But Theodoric's work left one major question unanswered — a light ray suffering one internal reflection can be turned through a whole range of angles, all the way up to 180°, depending on its impact parameter (Fig. 1). Why then does the rainbow correspond only to those rays that are turned through about 138°? What happens to the other rays?

Clearly some kind of enhancement effect takes place at 138°. But why does this occur? It was Descartes (1596–1650) who gave an answer to this question. Descartes laboriously calculated the paths traversed by rays entering the drop at various impact parameters, using the laws of refraction and reflection, and discovered from the calculations the existence of a particular ray which suffers deflection through a minimum angle. A ray which enters with zero impact parameter, that is, hits the drop dead centre, will be sent back along itself after one internal reflection. It has been turned through 180°. As the impact parameter is increased, the deflection angle *decreases* until it reaches a minimum of about 138° when the impact parameter is approximately seven-eighths of the radius. A further increase in the impact parameter of the ray results in an *increase* in the deflection angle. In other words, all the incoming rays which suffer one internal reflection emerge within a cone which we may call the 'Descartes cone' (see Fig. 5, p. 32) whose angular width is about 84° (2 × 42°). Further, there is an enhancement of intensity at the surface of this cone, which is made up entirely of rays which suffer minimum deflection (see box below).

Without this enhancement, no rainbow would occur. Each ray of light would no doubt be split into various coloured rays which would then emerge at different angles (because the angles of refraction are different for rays of different colour), but each of these coloured rays would combine with the emergent rays produced by rays entering at other impact parameters. The unravellings of one portion of the water drop would ravel with the complementary colours from other portions of the drop, other incoming rays, and the net result would be, again, white light. This is, in fact, what happens at all angles other than at the minimum angle. The minimum angle is different for rays of different colour, varying from 137° 58′ for red light to 139° 43′ for violet light. The Descartes ray for red light does get mixed with the V, I, B, G, Y, and O rays emerging at 137° 58′ from other incoming rays, but these are not enhanced and their contribution is lost in the dominant red. At other angles between 137° 58′ and 139° 43′

The phenomenon of light scattering

A rainbow occurs because light intensity is enhanced in the vicinity of the ray which suffers minimum angular deflection, that is, the Descartes ray. Why this happens can be understood by closely examining Fig. 2 which shows the quantitative relationship that exists between the impact parameter of a ray and its angle of deviation. The two curves shown represent the two classes of rays which suffer one internal reflection (A), and two internal reflections (B), respectively. As we have noted, though the incoming beam of light consists of parallel rays with uniform intensity, after these rays are turned around by the raindrop, the energy transmitted per unit angle is not constant, but depends on the angle. Consider the curve A. The energy scattered into the angular region between 160° and 165° originates in rays with impact parameters lying in region β. That which is scattered between 140° and 145° comes from the region α of impact parameters. Clearly there is more energy scattered into the five degrees around 140° than into the five degrees around 160°.

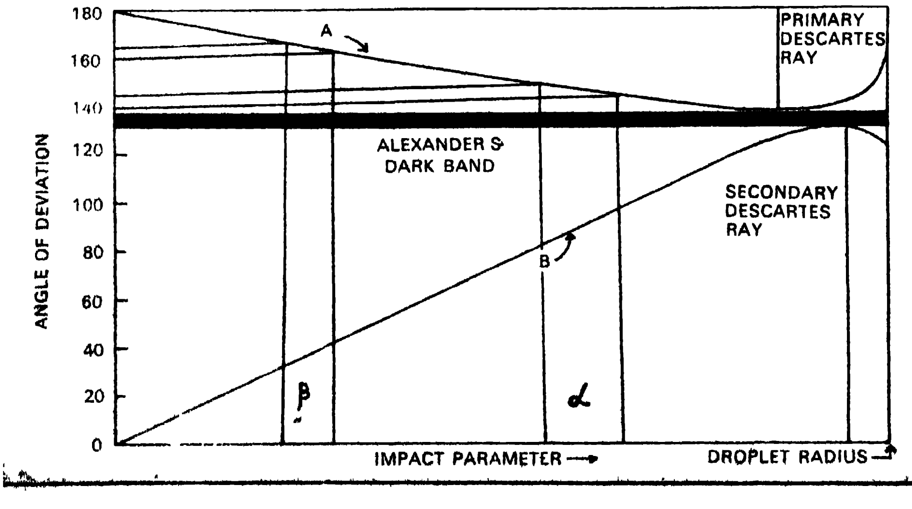
The angular intensity of light is just the light energy which is scattered per unit angle. It can be calculated by taking a small angular region, finding out how much energy dE is scattered into it, and then calculating the ratio. A little thought will lead to the result that this intensity is essentially proportional to the slope of the curves in Fig. 2 at that angle. But notice that the slope of the curve becomes infinite at the point where it is vertical, that is, at the point where it folds over. At this point, the intensity is very large, which is what we mean by 'enhancement'.

A more sophisticated way of saying that the slope of the curve becomes infinite is to state that the projection mapping from the cross-sectional area of the incoming beam to the solid angle space which parametrises the outgoing rays, becomes singular at the Descartes ray. Such a singularity is known as a fold singularity. The reader who is even more mathematically sophisticated will be interested to know that the rainbow is an example of a 'catastrophe' in the sense of Rene Thom's theory (see Science Today, September 1975). It is the simplest catastrophe that can occur — the so-called 'fold catastrophe'. The interested reader is referred to E. C. Zeeman's article in the *Proceedings of the Tokyo Conference on Manifolds* (1973), where the characteristics of the catastrophe, namely the 'control space', the 'state space', the 'potential function' and the 'bifurcation set', are all identified explicitly. The latter consists of a single point, namely, the Descartes ray.

Catastrophe theory has beautiful applications to the entire area of light 'caustics', which are the curves and surfaces along which light is concentrated after undergoing reflections or refractions. The cusped curve in the tea cup is none other than the second simplest catastrophe namely the Riemann Hugoniot catastrophe.

V.M.

Fig. 2



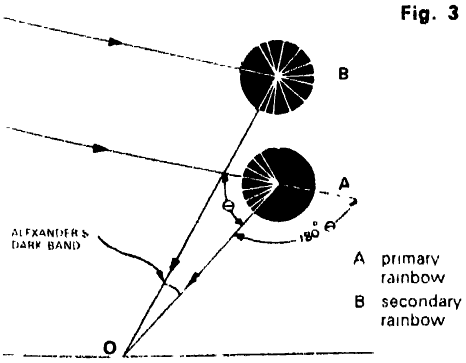
other colours are enhanced and dominate.

Both Theodoric and Descartes realised that the different coloured rays of the rainbow emerge at different angles, and that hence, in an actual rainbow, these rays emerge from different drops. But did they realise that white light is composed of different colours? If they didn't, how is it that they missed this conclusion? What explanations did they offer in its stead? Why is Newton, whose work followed Descartes's by a few decades, usually credited with the discovery of the composition of white light? These are intriguing questions of a historical nature that we shall not go into here.

On the basis of his investigations, Descartes was able to explain all the commonly noticed features of the rainbow phenomenon. Even though each drop is capable of producing a spectrum, and, in fact, does, we do not see all of this spectrum, but only that part which reaches our eyes. We see a Descartes ray of a specific deflection angle (that is, specific colour) only if the line joining the eye to the raindrop lies along that ray (Fig. 6, p. 32). When does this particular alignment occur?

Because the Sun is so many millions of kilometres away, the Sun's rays impinging on the falling water drops are approximately parallel to the line joining the Sun to the observer. Thus, if the drop-observer axis makes an angle of θ with the Sun's rays, the observer will see those rays which have been turned through an angle of 180° — θ (Fig. 3). Since the Descartes rays are turned through angles between 137° 58′ and 139° 43′, the drop-observer axis will contain a Descartes ray only if it makes an angle of between 42° 02′ and 40° 17′ with the Sun-observer axis. This defines a region shaped like a circular ring of angular width 1° 45′. A single falling drop, as it falls through this region, would suddenly appear in red, continuously metamorphose through orange, yellow and blue, finally taking on a pure violet before vanishing into the black yonder. But a rainshower consists of many drops. As one drop falls, another takes its place. Each of the numerous drops takes in the parallel rays of the Sun, and spins them out into its Descartes cone. The eye, if it is properly situated, picks up a thin sliver of this cone. And thus, even though each individual drop produces its own rainbow, the rainbow that we actually see is the product of the collectivity of drops in the falling rainshower. It follows from the above argument that no two observers see the same rainbow (see p. 32).

Fig. 3



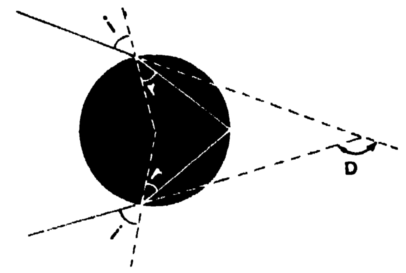
What we have discussed so far takes care of most of the principal features of the primary bow — its colours, its shape and angle. What about the second rainbow that is often seen above the primary, with its fainter

An infinity of rainbows

Because a sphere is a very simple object, it is not difficult to obtain an analytic expression for the angle of minimum deflection for rays which have suffered *n* internal reflections, with *n* taking values *1*, *2*, *3*, ...

Let us consider the case $n = 1$. We first note that the entire path of the ray, from its moment of incidence to the final emergence, is contained in a single plane which also contains the centre of the spherical drop. This reduces the problem to a consideration of a circular section of the sphere depicted in Fig. 4a.

Fig. 4a



Let *i* be the angle of incidence and *r* the angle of refraction. Then it is a simple exercise in school geometry to show that the angle of deflection $D = 2\ (i - r) + (\pi - 2r)$.

The case of multiple internal reflections is no more complex and the reader who has reached this far will have no difficulty in proving that for *n* internal reflections,

$$D = 2(i - r) + n(\pi - 2r)$$

Those familiar with calculus know that the condition for a minimum or maximum is that the first derivative of *D* should be zero,

that is, $dD = 2di - 2(n + 1)\ dr = 0$
or, $di = (n + 1)\ dr$ . . . .(1)

Now, the relation between *i* and *r* is given by Snell's Law

$\text{Sin}\ i = \mu\ \text{Sin}\ r$ . . . .(2)
where μ is the refractive index of water with respect to air.

With pencil and paper, the reader can eliminate *r* from equations (1) and (2), to obtain the result that the angle of incidence for the Descartes ray which suffers *n* internal reflections must satisfy the relation.

$$\text{Cos}\ i = \sqrt{\frac{\mu^2 - 1}{n^2 + 2n}}$$

Figures 4b, c, and d show the paths of rays which undergo 2, 3 and 4 internal reflections, and which are responsible for the secondary, tertiary and quaternary rainbows. Note that the tertiary and quaternary rainbows, if they were bright enough to be seen, would appear in the east at dawn, and in the west at dusk.

Fig. 4b

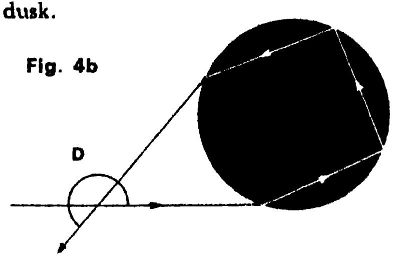


Fig. 4c

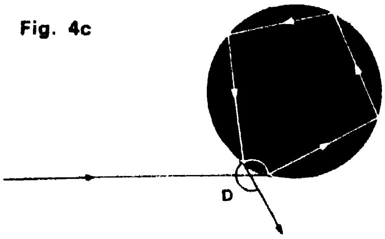


Fig. 4d

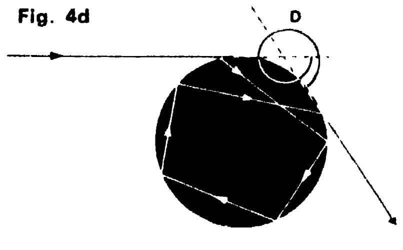
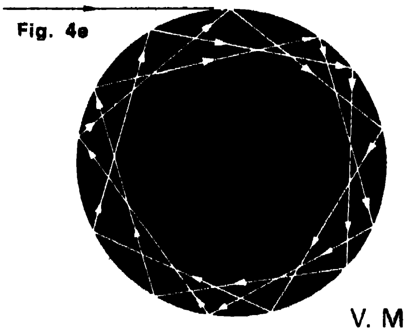


Fig. 4e shows the path of a 'trapped ray'. Such paths form closed polygons within the drop and are characterised by $n \to \infty$. These rays and rays in their vicinity do not give rise to rainbows, but to a related optical phenomenon known as the 'glory', which *is* visible to the naked eye, despite the large value of *n*

Fig. 4e



V. M.

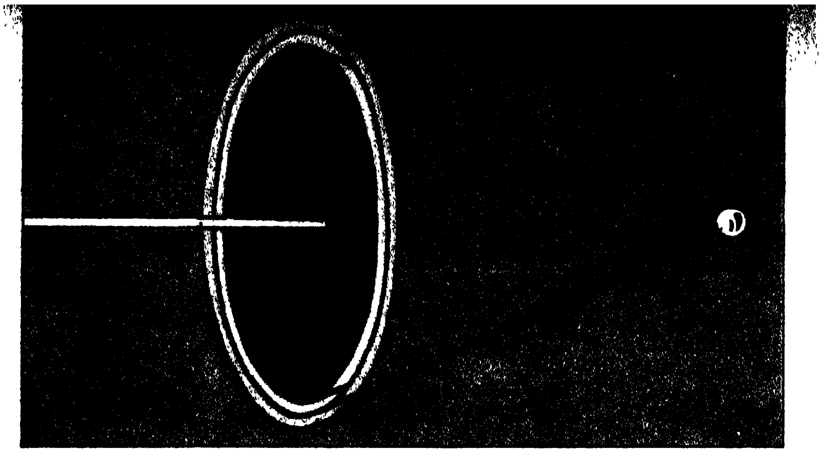


Fig. 5 The Descartes cone

reversed colours? Consider the rays that undergo not one, but two, internal reflections before emerging from the drop (Figs. 2, 4). The ray that is incident dead centre would, after two internal reflections, proceed along its original direction, that is, would experience zero deflection. If, as we did earlier, we consider rays with larger impact parameters, the angle of deflection would increase. But here, too, there is a definite impact parameter at which this process stops and a further increase in the impact parameter only reverses the process. Except that the Descartes rays in this case undergo maximum deflection (about 130°), the rest of the matter is quite analogous to the primary phenomenon, including the enhancement that takes place at the maximum angle which gives rise to the secondary bow. The reader can easily reconstruct the details to understand why the colours appear in reverse sequence. Why don't we *always* see the secondary bow? This, too, the reader can easily answer after a little thought.

The theoretical development up to this point leads us to inquire about rays which undergo *three* internal reflections, or more. Do these also give rise to rainbows? They do. In principle each raindrop gives rise to an infinite number of rainbows (see box on p. 31). Beyond the secondary bow, these are usually too faint to see with the naked eye, because each additional reflection cuts off some intensity. But there should be no difficulty experienced in seeing them in the mind's eye next time you look at a rainbow. The logical conclusion of such a theoretical development are rays that undergo an infinite number of internal reflections, that is, are trapped, never to escape. Is there any observable phenomenon connected with such rays, and rays in their vicinity? Surprisingly, there is.

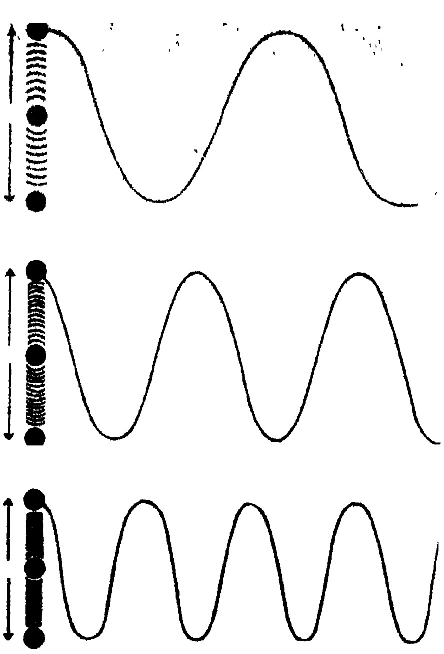


Fig. 7 The colour of the radiation emitted by an oscillating electron depends on the frequency of the oscillation (see box on p. 34)

It is precisely such rays that are responsible for an optical phenomenon, known as the 'glory', which, due to restraint of space, we cannot go into here.

Coming back to the primary and secondary rays, we notice that all the secondary rays should lie *outside* a cone of angle 50° (Fig. 12). Therefore, the region between these two angles should be devoid of any rays which have two internal reflections or less, and hence should be darker than the surrounding sky. It is claimed in the literature that such a dark band exists between the primary and secondary bows. It has even been given a name "Alexander's dark band"

Another intriguing phenomenon which allegedly occurs is the existence of pink and green bands just inside the violet band of the primary rainbow. These were explained only in the 19th century by the great master of physical optics, Thomas Young (1773–1829), who was the first to prove that light travels as a wave. A characteristic of wave phenomena is the occurrence of

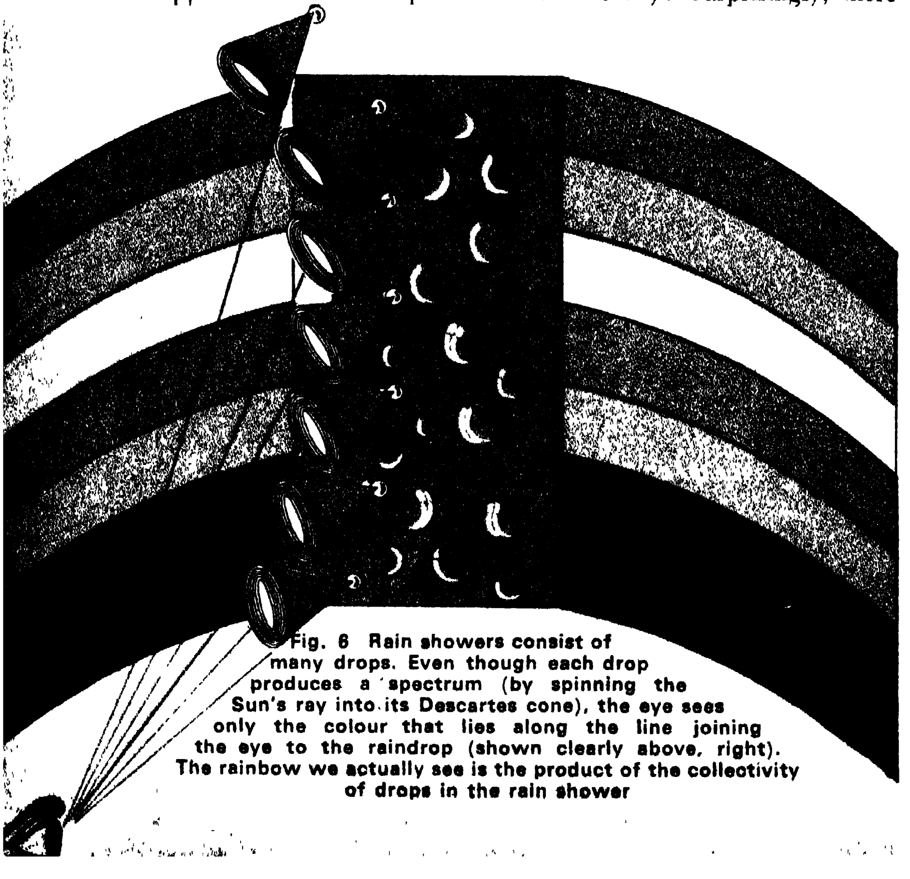
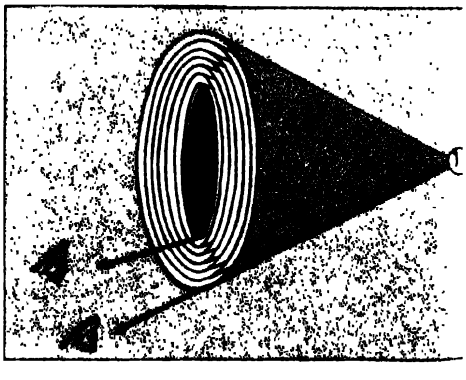


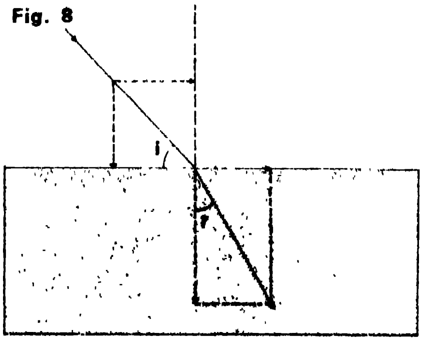
Fig. 6 Rain showers consist of many drops. Even though each drop produces a spectrum (by spinning the Sun's ray into its Descartes cone), the eye sees only the colour that lies along the line joining the eye to the raindrop (shown clearly above, right). The rainbow we actually see is the product of the collectivity of drops in the rain shower



The Wave Form

Rainbows, or any other refraction phenomena, are the outcome of the bending of light rays when they leave one medium (say air) and enter another (like water). Why does this happen? The first explanation of this fact, due to Newton, assumed that light consisted of moving particles. As these particles enter the water, they receive an impulse perpendicular to the surface boundary at the point of entry. The component of the velocity tangential to the boundary remains unchanged. The net result (obtained by adding the tangential component to the new augmented perpendicular component) is that the speed of the particles increases and their new direction is bent towards the perpendicular (Fig. 8). Thus, according to this theory, the speed of light in water is larger than that in air.

Fig. 8



These speeds were measured by the ingenious method due to Foucault (1819-1868) using long pipes filled with water. The result was exactly the reverse of that required by Newton's theory — light slows down when entering water from air.

But this result was consistent with an alternative explanation given by Young built on the hypothesis that light moves as a wave But what do we mean by the motion of a wave? What is it that moves? The answer to this question has its subtleties.

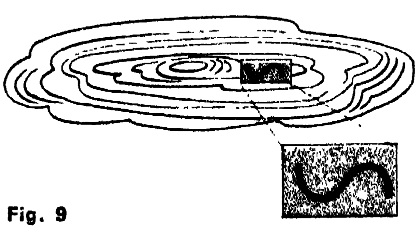


Fig. 9

If we examine the pattern produced when a pebble is dropped in a pond, it seems perfectly obvious that the ripples move outward from the centre in concentric circles. But what is a ripple? And what is meant by its motion? We may say that it is the crest of the wave that moves. And the same may be said of the trough between two crests — or for that matter any intermediate state between two crests. We may summarise by saying that the entire *wave form* shown in Fig. 9 moves outwards, which is another way of stating that "the ripples move".

By contrast, the water particles themselves do not move outwards with the ripples, but merely up and down — as can be seen by watching an object floating on the surface as the ripples go past it. What is the connection between the up and down motion of the water particles and the forward motion of the wave form?

Let us follow the sequence of events from the moment the pebble hits the water surface. The water molecules at the point of impact are pushed downwards, but restoring forces come into play and they are pulled back up. As they move back, they overshoot their original position and continue upwards until restoring forces again succeed in pulling them back and so on. In a word, they execute an up and down oscillatory motion much like that of a weight oscillating on a spring or the (sidewards) swing of a pendulum. This motion is known as 'simple harmonic motion'.

The restoring forces mentioned above are of course due to the interaction of the molecules in question with their immediate neighbours. But as Newton first put it, every action is accompanied by its reaction, and these neighbouring molecules themselves cannot remain undisturbed. They, too, will experience forces which set them moving up and down. In such a manner the disturbance moves outwards and more and more water particles are set into oscillation. The disturbance takes some time to propagate outwards, and the more distant particles start their motion later. The above qualitative description can be made more precise.

There is an intimate connection between the motion of a point on a circle and simple harmonic motion — a connection that is obvious to anyone who has observed how a steam engine is set rolling by the back and forth movement of its piston. Briefly, if P is a point on a circle (Fig. 10), and Q is its horizontal projection on a diameter, as P moves with uniform speed on the circle, Q will move back and forth in simple harmonic motion. There is a one to one correspondence between the state of motion of P and that of Q — for every position of P, there is a unique position and velocity of Q. We can make use of this fact to parametrise simple harmonic motion. P's position on the circle can be aptly described by the angle θ which the radius QP makes with, say the X-axis OX. As θ varies from 0 to 360°, P moves once around the circle, and Q moves away from O, up, down, and back up to O.

The maximum upward displacement of Q from its 'zero position', corresponds to $\theta = 90^\circ$, and the maximum

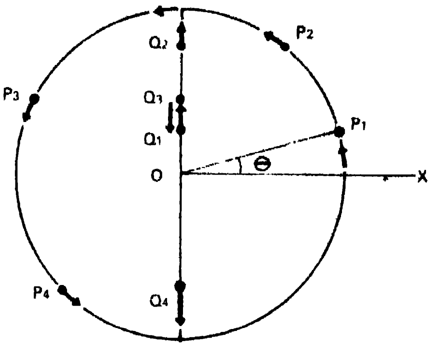


Fig. 10

downward displacement to $\theta = 270^\circ$. Each value of θ corresponds to a definite state of Q's motion. This angle θ, is known as the 'phase' corresponding to that state, or more briefly, the 'phase of the motion'. 'Phase' is a concept that is applicable to any simple harmonic motion, for it is easily seen that the above procedure can be reversed and a uniform circular motion constructed to correspond to the simple harmonic motion.

Coming back to the example of waves on the water's surface we observe that though each point on the surface does execute SHM, the phases of different points at any one time are not identical. All points on a crest are at phase 90°, all points in a trough are at phase 270° — and so on. The actual ripple-profile, or wave form, at any one instant is the shape which is formed out of the instantaneous positions of innumerable simple harmonic oscillators, in different phases. Fig. 11 indicates the relative phases for a small section of the actual wave form.

At a slightly later instant, each oscillator has moved to a new phase, and correspondingly the wave form also has undergone a change — the crests and troughs 'move' to new positions. This is what is meant by "the motion of a wave". If a given point is on a crest (phase 90°), a little later its phase will have changed, but a nearby point will now be at phase 90° — that is, on a crest. The same argument holds for any phase θ. If a water particle is at phase θ, after a little while, a nearby point will be at phase θ.

Thus, the speed of the wave is the speed at which a region of constant phase θ moves along the water's surface — be it a crest ($\theta = 90^\circ$) or trough ($\theta = 270^\circ$). What happens when a wave slows down is that the progress of each region of constant phase is retarded. Why this happens when light enters water or glass from air is discussed in the box on p. 34.

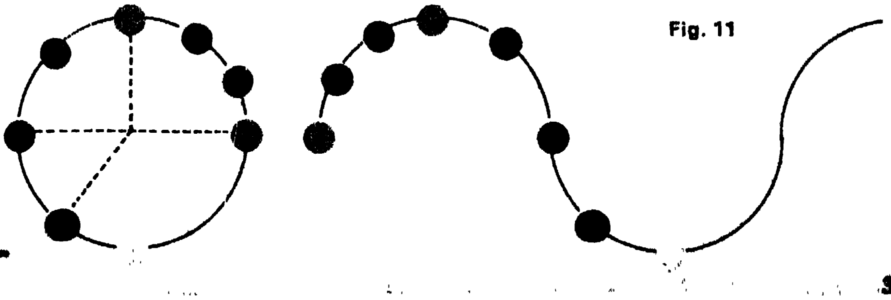


Fig. 11

The wave theory of light and the origin of the refractive index

By showing that two beams of light could cancel each other out, or augment each other, to produce bright and dark fringes, that is, by showing that light exhibits the phenomenon of interference, Young conclusively proved the wave nature of light. What are these waves? How are they produced when we light a candle or turn on an electric lamp? Why do they slow down when they enter water from air?

James Clark Maxwell (1831–1879), in what was one of the greatest discoveries of all time, showed the relation between electromagnetic waves and light. If you take an electrically charged object, say an electron, and move it back and forth in simple harmonic motion, it will begin to emit electromagnetic waves. As you increase the frequency of the electron's oscillation, the frequency of the waves will also increase. At about a hundred thousand back and forth motions per second, you will be producing radio waves. A still further increase in frequency will result in the waves on which television is broadcast.

When an electric charge oscillates at the enormous frequency of 400,000,000,000,000 cycles per second, it will begin to emit a red coloured radiation which is nothing other than red light. Thus, radio waves, heat radiation, light, ultra-violet and X-rays are all very similar to each other, the only difference being essentially like that between a high-pitched sound and a low tone, namely, a question of frequency. This was the remarkable discovery of Maxwell.

When you light a candle, or turn on a lamp, in some way the electronic charges in the candle's inflammable material or in the lamp's filament are set oscillating, and what we see is their electromagnetic radiation. It follows that sunlight is the outcome of the agitated oscillations of innumerable electric charges in the Sun's material, whose electromagnetic output reaches us eight and a half minutes after the event.

This answers the first question, but what about the second? Why does light slow down in water or glass? In the box on p. 33, we saw the relation between the phase of a wave and the concept of the 'speed of a wave'. Clearly, the light on entering the material of the water or glass must interact with the microscopic matter in such a way that the phase of the waves gets retarded in the process.

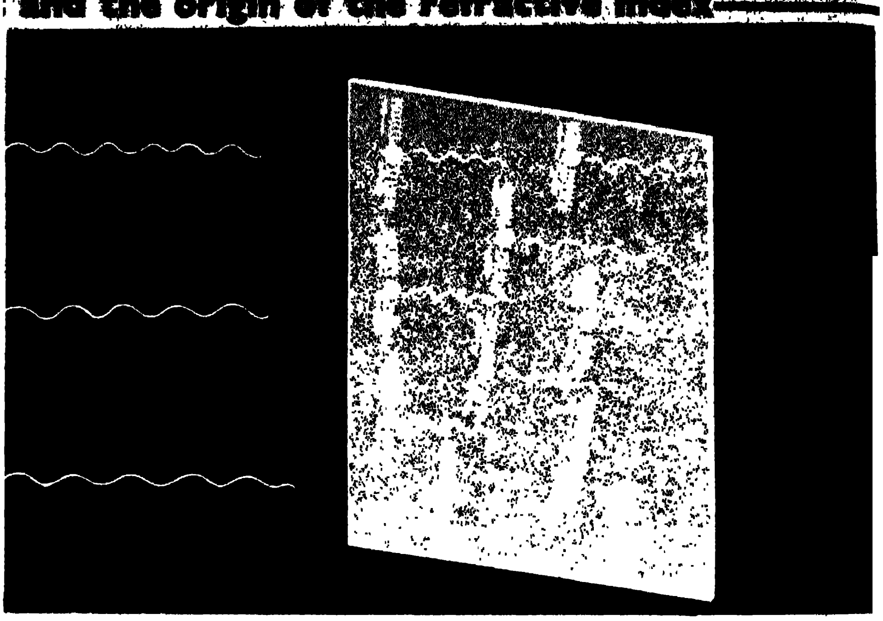


Fig. 13

To understand how this happens, we have to look at the reverse of what we have just discussed, that is, the effect of electromagnetic radiation on electric charges. This is simple to describe. If an electromagnetic wave of a certain frequency impinges on an electric charge, the charge is subjected to an oscillating force that sets it oscillating with the same frequency as the wave. So when light is incident on water, the electrons and protons which make up the molecules of water experience oscillating forces. But the protons being heavy don't move much and the electrons do most of the jiggling around. As soon as they begin oscillating, they, too, radiate electromagnetic waves which add to the original electromagnetic light wave. The different patterns of collective radiation of these oscillating electrons in different materials account for the different optical properties, (like opacity, transparency, reflectivity, colour, etc) of these materials.

A simple situation arises when we consider a case in which all the atoms are arranged in a thin sheet, of infinite length and breadth, which is perpendicular to the incoming wave (Fig. 13). Though each electron will oscillate in phase with the wave, the effective electromagnetic field at any point is the sum of the contributions of all the electrons in the sheet, plus, of course, the contribution of the original wave (this is known as the principle of superposition). When all these contributions are added up, it turns out that the result is a wave which has its phase either retarded, or advanced, with respect to the original wave. The change in the phase depends crucially on the relation between the frequency ν of the incoming wave, and the natural frequency ω of oscillation of the electrons

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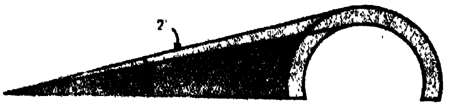
interference ' where two waves arriving at the same point can cancel each other out or augment each other depending on their phases (see box on p. 33). Young proposed that two rays situated on opposite sides of an incoming Descartes ray, which emerge at the same angle, will interfere with each other and lead to the cancellation of light of certain colour and the augmentation of other colours. (Rainbows in thin oil films floating on the surface of a pond are also due to the same effect.) Thus, interference, and not dispersion, explains the extra pink and green bands.

Fig. 1-2



An important shift in theoretical perspective has occurred in Young's explanation. Descartes and Newton worked with a ray theory of light, or what is today known as ' geometrical optics '. But light propagates as a wave, and the ray description is only approximately valid. Young's explanation of the interference bands was a hybrid of these two. His point of departure was also ray optics, except that he treated the rays in the vicinity of the Descartes ray in accordance with the wave theory. A more correct description would be fully based on the wave theory — the problem may be formulated as the analysis of the "scattering of a plane wave by a spherical obstacle". Though the mathematical solution, in principle, is not too difficult, it is known only in the form of an infinite sum over a sequence of, so-called, special functions. In practice, such sums are performed on a computer, but in the early years of this century, computers were not available and the computation of the scattered intensity involved what has been described as ' heroic efforts '. The most comprehensive of such early computations was done by an Indian physicist, B. Ray (1923 *Proc. Ind. Assn. for the Cultivation of Science*, **8,** 23).

To a thorough-going scientist, it is never quite satisfying to have to go to a computer to work out the details of in the atoms. If ν is smaller than ω, the phase is retarded, whereas if ν is larger than ω, the phase is advanced.

When light is incident on a bulk of material like water, we can imagine that this bulk consists of many thin sheets of atoms adjacent to each other. In passing through each sheet, the phase of the wave is progressively retarded. In simple terms, the speed of the wave is reduced. This happens, of course, only because the frequency of light is less than the natural frequency of the electrons in the atoms. What would happen if the incident radiation had a frequency larger than this natural frequency? Would light speed up? Could the speed of the light in the material in such a case be larger than that in air or vacuum? Yes, it can, and there are many examples of such phenomena, which are quite important in, say, the study of the transmission of radio waves through the ionosphere. Does this fact violate the theory of relativity, which is built on the hypothesis that no signal can travel faster than light in vacuum? No, it doesn't, but the explanation of this assertion is a subtle matter which we cannot take up here.

In summary, the origin of the refractive index lies in the interaction of electromagnetic radiation and electric charge, that is, in the interaction of the light beam and the electronic oscillators in matter.

For a given material, the natural frequency of oscillation ω is fixed. It depends on how strongly the electrons are bound to the nucleus. But two beams of radiation with different frequencies ν, ν' (different colours) will interact differently with the electron oscillators, and experience different retardation of phase. The speeds of these beams in the refracting matter will differ. Their rays will be turned through different angles. Thus, the phenomenon of *dispersion*, or the splitting of a white beam into its constituent colours, can also be understood in terms of the differential response of a material oscillator to external forces of different frequencies. V.M.

a solution. A computer is always the last resort, something to be availed of when the theoretical effort has reached an impasse. There is a good reason underlying this attitude. The various mathematical transformations and approximations that are used to progressively simplify the original problem, to make it more tractable, are not merely tricks to avoid the ' brute force ' of the electronic computer, but more often than not represent some genuine physical relations and interconnections which lie hidden beneath the phenomenon, to be unearthed by the theorist's analysis.

The ray optics and the wave optics are not merely two different approaches to the same problem, one less, the other more accurate, one [illegible], the other more difficult. The existence of two radically, one might say, structurally, different descriptions of the same phenomenon always throws up the question of identifying the relations between the two. And, as was pointed out earlier, these relations are not only mathematical niceties, but may very well represent genuine physical insights. So the search for intermediate descriptions, somewhere between arrow and ripple, between geometrical optics and wave optics, continues. Thomas Young's explanation of the interference bands was only the first. The problem was later taken up by the mathematical physicist, George B. Airy, who in the course of his investigations discovered the mathematical functions that bear his name. It is still very much alive, and the last five years have seen some important advances in the work of H. M. Nussenzveig and V. Khare (1974 *Phys. Rev. Letters*, **33**, 976-980).

In a slightly different form, the problem reappears in the question of the relation between classical mechanics and quantum mechanics. The pure mathematicians who investigate the relation between the global geometry of various mathematical spaces and analysis on these spaces may also have much to say about the problem even if their immediate concerns do not encompass the passage of light through matter. The latter two areas of investigation lie on the extreme frontlines of modern scientific research, an extremism which is manifested in triple measure -- fundamentality, interrelatedness and beauty. It is likely that further advances in the theory of the rainbow will take the investigator to these distant boundaries.

But perhaps it is not necessary to venture so far in the search for fresh insights. In a recent paper (1972 *J. Atmos. Sci.*, **29**, 211) a physicist, A. B. Fraser, has drawn attention to the fact that while the red colour in other portions of the rainbow is never pure (this was well known for a long time), the red in the vertical portion of the rainbow (which can be seen when the Sun is low on the horizon) is an exception. Until Fraser pointed this out, apparently, this feature had neither been noticed, nor predicted.

Which is something to keep in mind when you next look at a rainbow.

Dr. Vivek Monteiro (27) did his MS from the California Institute of Technology and his PhD from the State University of New York, USA, and, till recently, was with the Theoretical Physics Group at the Tata Institute of Fundamental Research, Bombay.

IN LIGHTER MOMENTS

James Watt's life-long partner Boulton was not only a clever designer, a far-sighted engineer and a very able businessman, but also witty and blunt at times. Once King George III and Queen Charlotte visited his famous Soho Manufactury and admired the machines and engines made there, though without ordering for any of them. Disappointed, Boulton told the Royal couple: "Never was man so complimented as I have been; but I find that compliments alone do not make fat nor fill the pockets."

On another occasion when Dr. Johnson and his biographer Boswell visited the factory and the latter told Boulton that they were deeply impressed by the vastness and ingenuity of the machinery, the engineer-businessman impressed them most when he said "I sell here, sir, what all the world desires Power."

There has always been a fair number of the absent minded and the eccentric in the scientific community. For example, the 18th century French chemist Guillaume Francois Rouelle had become a regular headache to his students. In the course of his lectures, Rouelle used to take his clothes off one by one as he felt hot, and hung them up on different apparatuses. And then when he needed some apparatus for some demonstration, he would wander round store rooms looking for it.

Rutherford's moodiness is well known. Once, when a young assistant in his physics department at Manchester asked him to sanction payment of a few shillings for a new spring balance for a sonometer, he growled at him, "Why must you always have money? Why can't you learn to improvise? Why don't you hang beakers on the ends of the wires and load them by pouring in water?" The young man naturally felt put out, but gathered strength to politely ask the teacher, 'Sir, what do you think would be the cost of a beaker large enough to hold 25 pounds of water . . . and how long would it last before it meets its certain fate?" And it did the trick. Though he was surprised at the assistant's impudence, Rutherford could not help laughing at his own behaviour.

Most people are familiar with the story of Galileo's experiments with different weights dropped from the Leaning Tower of Pisa, but it seems to be no more than a legend. In fact, Galileo himself never claimed credit for the experiments. It seems that the experiments were made by Simon Stevinus of Holland (in 1586), and John Grotius, who dropped lead balls of different sizes and weights and found that their speeds were apparently the same. Later they observed that a ball of thread fell faster than a single thread.

S. N. MUNSHI

Young teak in bloom (Photo by S. R. Nayak)

let's get to know our trees!

6 SOME DECIDUOUS FOREST TREES

There is something about a wilderness that is intangible and inexplicable, but real enough, that draws people to it and makes them strike up an acquaintance with the greenery — each individual according to his own style, be he an artist, a biologist, an ecologist, or a picnicker wondering what was the tree that shaded him during those few relaxing hours!

Since very ancient days, trees and other forest flora have interacted with the living and non-living elements in their environments and a measure of order has emerged in different regions, and associations of tree species have arisen, giving rise to what forestry specialists call forest types. Depending upon such associations one may discern such types as deciduous forests, evergreen forests, and so on.

A deciduous tree which is so common as to be almost taken for granted is the **teak** tree (*Tectona grandis; sagwan* in Hindi). It is indigenous to the Indian peninsula and is also specially planted and managed in many types of forest areas for its excellent and valuable timber, famous the world over for every conceivable type of constructional and furniture work. Also commonly known as Indian oak or ship tree, the teak is a large tree with a thick straight trunk and light ashen-grey bark, the outer layers of which peel off from time to time in thin, long flakes. In old trees, thick flutings in the lower part of the trunk can be seen to go down to merge with buttresses which help to support the tree.

The leaves fall off during the cold season from November to January and the tree remains leafless, a bare skeleton as it were, till late summer; from April to June new leaves appear, with a spurt during the rains. The oval leaves attain very large sizes, about 60 cm long and over 30 cm broad. Throughout their growth, the leaves are characteristically very rough, heavily ribbed with veins and covered with a soft, brown, downy fur. The leaves are generally opposite to each other and arise from branchlets with square (on cross-section) stems. An interesting feature of young leaves is their elasticity; it is possible to pull a young leaf blade and watch it spring back into shape when released — a feature not seen in mature leaves which are brittle.

With the onset of the rains, the teak begins to flower — in about the month of June, but most trees are in full bloom in August or September when the end branches towards the top of the trees are heavily clothed in branching panicles of small whitish-yellow flowers. After each burst of rainfall, numerous flowers can be seen strewn around the base of each tree. This may, perhaps, explain why the fruits that appear from November to January are much less in number compared to the profusion of flowers sported by the tree. The teak fruit is hard, somewhat roundish and hairy, with usually two seeds encased in a bony endocarp; the fruit itself is enclosed in the persistent calyx which is enlarged into a thin, papery envelope, almost like a brown paper bag in miniature! The hard seed coat is a boon for the small white seeds for it protects them during forest fires; in fact, some authorities believe, given good moisture, the high temperature caused by fire may actually stimulate germination.

Some of the finest teak trees, many of splendid proportions, can be seen in the forests of Chandrapur (Maharashtra) and Madhya Pradesh. (The forests of Burma have been outstanding for teak. Teak plantations have also been set out in some parts of Central and South America.) Teak timber, especially that from the heartwood, is among the finest in the world, very durable and fungus-resistant owing to the presence of some chemical compounds. Much of our knowledge of the chemical constituents of our flora has come from the masterly application of the art of chemistry by the late Prof. T. R. Seshadri and his co-workers: teak, for example, was shown to contain anthraquinone and naphthalene compounds.

Destructive distillation of teak wood yields a wood-tar which has been used for medicinal purposes. For example, the Gonds of Bastar are reported to apply this in skin diseases; an application of the wood-tar to sores in cattle to prevent the development of maggots is known from western India. The seed oil is used in indigenous medicine to treat scabies, and to promote hair-growth. The flowers are used in liver disorders (biliousness) and respiratory conditions. Handling raw teak timber may cause an allergic skin condition like eczema in some persons; the offending sensitising agent is believed to be a chemical called lapachol.

The large leaves of teak are often used by village folk as makeshift umbrellas and as thatching material. The young twigs and leaves are browsed on by cattle.

The teak tree is fairly long-lived, probably 200 years or more. Its antiquity in India is almost unquestioned for teak timber about 1,000 to 2,000 years old have been found among ruins of temples in western and southern India. (However, according to S. K. Basu, formerly of the State

Forest Service, West Bengal, the teak had not been introduced into India from South-East Asia even as late as 4th century AD — a conclusion drawn from the fact that neither Valmiki nor Amarsinha, the lexicographer, had mentioned this tree in their writings.)

Another tree encountered in deciduous forests, often in association with the teak, is the **shisham** or rosewood tree (*Dalbergia* species). Over a score of *Dalbergia* species are found in India, consisting of trees, shrubs and woody climbers. Two of the most important ones are *D. latifolia* and *D. sissoo*, both of which are known by the same common Indian name, shisham. However, the tree referred to by both Valmiki and Kalidasa as *shinshapa* in Sanskrit is thought to be *D. sissoo*. The shisham belongs to the pea family and so shares some features common to the *karanj* and others (SCIENCE TODAY, July 1977) such as odd pinnate leaves, characteristic flowers and pods containing seeds (see p. 40).

Dalbergia latifolia, the Indian rosewood or blackwood, has leaflets which are oval or roundish, attached to a rather straight central stem (the rachis). This tree reaches a very great height and girth. The leaves are shed in February and March, and new leaves appear in April along with clusters of small yellowish-white flowers. However, in some regions of central and western India, the flowers bloom from August to October; the dark brown strap-like pods containing three or four seeds ripen from November to February. When cut down for timber, the tree coppices well, and natural regeneration also takes place through germination of seeds. Rosewood timber, especially the heartwood, is of an exquisite dark purple-black colour and is in great demand for fine furniture despite the fact that it is expensive.

Right: **Indian kino**

Below: ***Boswellia serrata***

Padekar

Dalbergia sissoo, on the other hand, has leaflets which are broadly ovate but end in a pointed tip and are set alternately on a rachis which appears to be zig-zag. This tree has a more northerly distribution and is found in the sub-Himalayan tracts where it prefers porous, gravelly soil close to rivers. In Haryana and Punjab, it is among the more common roadside trees on the highways. Old leave turn a reddish brown and then drop off in the summer followed by the growth of new leaves. The pale yellow flowers bloom from March to June and sometimes a second flush occurs during the rains from July to October with the pods following shortly after and these remain on the tree till about February. The mottled brown heartwood is strong and is used for making boats, carts and agricultural implements where elasticity is also required. The leaves are used in indigenous medicine as a bitter stimulant, and a mixture of leaf mucilage and sweet oil is applied to excoriated skin.

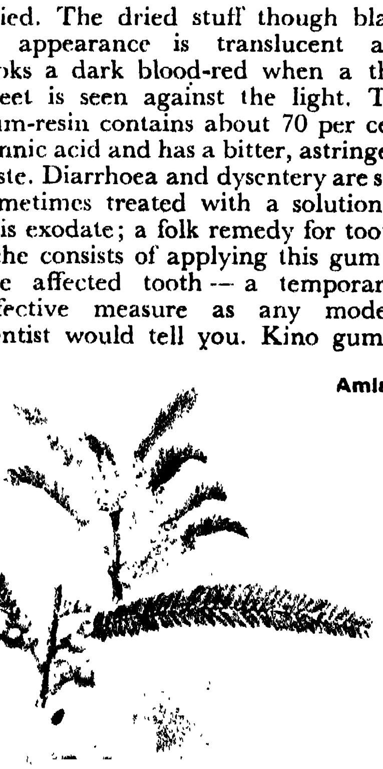
The shisham is perhaps one of the oldest trees in recorded history. Prof. C. D. Chatterjee has described the finding of remnants of timbers used by the chalcolithic peoples between 3500 and 2000 BC. One of the timbers found during the excavations at Harappa was that of the rosewood, *Dalbergia latifolia*.

An unusual member of the pea family, to an inexperienced eye at least, is the fairly large tree known as the Indian **kino** tree (*Pterocarpus marsupium ; bija* in Hindi). As the botanical name itself implies, the fruit of this tree is winged and does not at all look like a pod — the singular characteristic of the family. In Valmiki's *Ramayana* the tree has been referred to by its Sanskrit name *asan*.

The kino tree grows in the hilly regions of the Indian subcontinent from Uttar Pradesh southwards to Kerala and is found in the mixed deciduous monsoon forests. Where the soil and rainfall are good, as in the southern states, the tree grows to over 30 metres in height and about 2·5 metres in girth with a straight, thick trunk. The bark is dark grey and furrowed by cracks, though medium-sized trees may appear to be smoother. The leaves are oddly pinnate with five to seven leaflets, each about a finger's length and half as broad, arranged alternately on a thick rachis. During early summer it loses most of its leaves; in May and June a fresh crop of leaves appears along with the branches bearing small yellow flowers which are situated quite high up and may escape notice of the casual passerby. The fruits (pods really) ripen late in the year and remain on the tree till the next summer. Each pod is one-seeded, enclosed in a hard shell and surrounded by a thick membranous wing.

The heartwood of the kino tree is an important timber which is made into very durable items like railway sleepers, tools, boats, etc. Freshly cut wood contains a yellow substance which can stain cloth; on seasoning, the colour of the wood changes to dark brown. The wood can also be made into pulp for paper-making.

Kino bark contains catechins and a reddish-brown colouring material which is sometimes used to dye tussar silk a light red-fawn colour. On incising the bark of the living tree, a dark black liquid, kino gum-resin, flows out and this can be collected and dried. The dried stuff though black in appearance is translucent and looks a dark blood-red when a thin sheet is seen against the light. The gum-resin contains about 70 per cent tannic acid and has a bitter, astringent taste. Diarrhoea and dysentery are still sometimes treated with a solution of this exodate; a folk remedy for toothache consists of applying this gum to the affected tooth — a temporarily effective measure as any modern dentist would tell you. Kino gum is said to be odourless but I have found the fresh gum and its solution in water to have an odour of burnt wood mixed with a faintly aromatic smell which is not quite unpleasant.



Amla

Close-up of teak inflorescence
(Photo by S. R. Nayak)

An infusion of kino flowers is given to reduce fever, and crushed flowers are applied by rustic folk to boils, sores and skin ailments. An infusion of kino wood is believed to be anti-diabetic; Indian investigators have shown a blood sugar lowering effect of such wood extracts in mice and rabbits in the laboratory.

During February and March, when vast areas of deciduous forests are naturally defoliated, it comes as a pleasant surprise to find one tree species with a spectacular display of colourful leaves! This is the **kusum** tree (*Schleichera oleosa; kusumbha* in Sanskrit), the tender young leaves of which are dull red to scarlet in colour. When sunlight strikes the tree and sets the leaves aflame in colour, the breathtaking beauty easily rivals the flowering of *palas*, the flame of the forest. The leaves change rapidly to a bright orange and then to light green as they mature within a few days. Often trees can be seen generously daubed in all these hues simultaneously over entire hill slopes.

The kusum, also known as the *lac tree* and *Macassar oil tree*, is widely distributed throughout India except at altitudes above 900 metres, and under good growth conditions touches over 30 metres in height and about three or more in girth. The trunk is deeply furrowed and the bark flakes off in thick plaques. Kusum leaves are evenly pinnate with two to four pairs of opposite leaflets (see p. 40), each about 20 cm long and elliptical; the leaflets near the tip are longer than those closer to the base of the rachis. The minute yellowish-green flowers are borne on axillary racemes and bloom at about the time the new leaves mature. The fruits are ovoid and brown, either smooth or sometimes having short, thick, blunt prickles on the outer skin, measuring about two to three cm long and with a short, tapering tip. There may be one or two seeds in each fruit, surrounded by a fleshy white pulp (aril) which can be peeled off and eaten.

The kusum tree has a number of economic and medicinal uses. The most important is in the production of high-quality *lac* by the lac insects which can be inoculated upon this tree. Though the timber has excellent hardness and elasticity (required for hammers, tools, etc), generally foresters are loathe to fell the tree because it can be used for lac production. The aril of the fruit has a sweetish acid taste and is eaten during the summer heat for its cooling properties. Oil expressed from kusum seeds is said to be the original *Macassar* oil used medicinally. During the early years of this century, Sen and Bose investigated the oil which was used to adulterate edible oils and reported the presence of hydrocyanic acid which was responsible for cases of irritant poisoning. Macassar oil is used in native medicine as an application for treating acne and itch, and for external massage in rheumatism.

From early winter till the beginning of summer, especially between October and February, the light green globular fruits of the **amla** tree (*Emblica officinalis*) are brought in large numbers for sale in the bazars. These fruits, well-known from ancient times as *amalaka* in Sanskrit, are familiar to many, but the tree which bears them is perhaps known to few, except those who have moved in the deciduous forests where it grows, namely the Deccan forests, extending north and south to many parts of the Indian peninsula up to elevations of 1,400 metres.

The tree grows to a moderate height, branches profusely and has a smooth greyish-green bark, the outermost layer of which strips off naturally. The appearance of the leaves is rather deceptive — at first sight, one may mistake the small leaves, 1·5 cm long, to be leaflets arranged pinnately on a central rachis like those of the tamarind or the copper-pod. A closer examination reveals each tiny leaf to be an entire, single leaf, and the small flowers grow out from the axils of the leaves towards the lower ends of the branchlets. The small greyish-white flowers are unisexual (either only male or female) and the male flowers vastly outnumber the female ones, though both occur in bunches on the same branches. Though the flowering season is summer, the fruits ripen and grow to their full size of about 4 to 5 cm diameter in the winter.

The amla tree is also cultivated, and often budding and grafting are done to improve the quality, size and yield of the fruits. The hard stone inside the amla fruit is composed of three cocci compressed together, each containing two seeds, making in all six seeds per fruit. Varieties of the amla fruit are often distinguished according to the size, presence of yellow or pink-brown tinge and so on.

Almost all parts of the amla tree are considered useful in indigenous medicine, but the fruit pulp, either fresh or dried and powdered, is the part most commonly used. Amla fruit is said to be cooling, diuretic and laxative as well as carminative and stomachic. Commercially known as emblic myrobalan, it is one of the constituents of *triphala churna* of the Ayurvedic system of medicine, used for treating headache, indigestion, stomach complaints and liver disorders. The amla fruit is one of the richest sources of vitamin C — about 600 milligrams of the vitamin being contained in 100 grams of the fresh fruit. Fine preserves and pickles are made from the fruit. The firm and somewhat fibrous pulp is often air-dried and used as a masticatory in much the same way as the betel nut.

Both the bark and fruit contain tannins which can be used for preparing inks and hair dye. A dye extracted from the leaves has been used to impart a brownish-yellow tinge to tussar silk. Brandis mentions an interesting use of amla wood chips and crushed branches: when thrown into muddy or turbid water, it clears the water effectively. Amla wood is hard and durable, even under water, and is used for making agricultural implements and well-work.

Phyllemblin, a principle extracted from amla fruit, has been shown to have interesting biological properties when tested on laboratory animals — mild sedation, a spasmolytic action, anti-convulsant activity and an anti-tremor action.

The amla tree is also connected with Hindu religious ritual: both the *Kartik Mahatmya* and *Vrat Kaumudi* ordain the worship of this tree to be absolved of sins.

Another species of amla, *Emblica fischeri*, known to occur in restricted regions of the Western Ghats and Karnataka, is said to be a small tree with larger leaves yielding excellent fruit suitable for pickling and preparation of preserves.

A moderately large tree which is perhaps not familiar to the townsman but within the ken of village folk is the fairly widely distributed deciduous forest tree called **asna** (*Bridelia retusa*) which belongs to the same family as the amla, that is, *Euphorbiaceae*. This tree is not very conspicuous except at the end of summer and the commencement of summer rains when the fresh young leaves become noticeable because of their dull red-brown colour. The leaves are elliptical, about 10 to 15 cm long, with prominent lateral veins and a leathery feel. The asna tree bears both male and female flowers which are small, slightly yellowish-white and borne in spikes at the ends of the branches. The flowers appear from May to October, and fruiting occurs in the cold season. The small, round, soft-bodied fruits look like berries, each the size of a large pea; each contains one seed, and the dark purple-black pulp is edible, having a sweetish, but not flavoury, taste.

Asna timber is hard and is used for making agricultural implements. The *Smritisar Granth* advises the use of asna twigs as toothbrushes because the sap is clear and colourless.

By and large, the majority of trees in deciduous forests are not very attractive during the winter and summer months; the rains bring about a refreshing change by provoking a rank growth of foliage and the understorey. It is very difficult to select an outstanding tree from such a heterogeneous congregation of deciduous trees for really each species has its own special features and role in the balanced inter-relationships between them. A rather plain-looking tree, and one which, like many others, contributes to the ecology of the forest is the **kharpot** or **kakad** (*Garuga pinnata*).

A medium-sized tree with a fairly smooth grey-black bark and oddly pinnate leaves, the kakad is found in most regions of peninsular India. Between February and April, when the tree is completely leafless, it bears bunches of small greenish-white flowers on stalks at the far ends of its branches; the globular, fleshy, green fruits, too, are borne in a similar manner in June and for some time later when the new leaves emerge. The fruits resemble those of the amla and have a sour, astringent taste; they are often collected and made into pickle or chutney. The leaves are used as livestock fodder.

The kakad is fire-resistant and coppices well when felled; it also reproduces by producing root-suckers. For this reason, it is considered to be a good tree for reforestation. Towards the end of the year, large numbers of galls — small, smooth, round, red growths — appear on the mature leaves; these galls are produced by a proliferation of the leaf tissue provoked by infestation by an insect; each gall is hollow and contains the insect larva. (It is instructive to cut open a gall or two and observe the creature inside.) So numerous are the galls indeed that at first glance they may be mistaken for fruits by the uninitiated. The tree is apparently none the worse for the infestation for the leaves fall off as usual and the tree continues to grow as vigorously as ever.

People of Asia and some parts of Africa have for long been using frankincense (*luban*) either as a medicine or as a perfume when it is burnt. The substance is obtained as an exudate when the bark of trees of the genus Boswellia is incised. One species of *Boswellia*, *B. serrata*, is extant in India and is found growing, often gregariously, in the dry deciduous forests in the hilly tracts of the Deccan, Madhya Pradesh, north Gujarat, Bihar and Orissa. *Boswellia serrata* has been mentioned in the Valmiki *Ramayana* (*shallaki* or *kunduru* in Sanskrit) and is now known by its common Hindi name, **salai**, or the English name, the **incense tree.**

Kakad

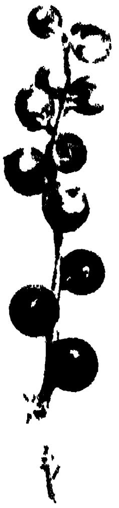
It is a medium-sized branched tree with a greyish-green flaking bark suffused with pink; in its natural habitat, the tree grows in association with other deciduous trees like the teak, karaya gum tree, and others. Salai leaves are oddly pinnate, clustered near the ends of the branches, between 20 and 40 cm long composed of eight to 15 pairs of leaflets. Leaves are shed in March and April when the minute white flowers appear on branching stalks at the terminal ends of the branches; new leaves grow in June and the fruits (three-valved capsules) develop later. The seeds are small and each has a membranous wing.

The salai grows rapidly and throws up abundant coppice shoots when felled; it even grows readily from cuttings planted during the rainy season. Its timber is rather soft and easily attacked by insects and fungi and hence is used for inferior types of planking, cases, etc. The tree is a host for the loranthus parasite, *Dendrophthae falcata*.

Mali

The gum-resin obtained by incising the bark is burnt as incense (*luban*). The true frankincense commercially available, however, is obtained from the African species, *B. carteri* and *B. frereana*, and is known as African olibanum Salai gum-resin is reputed in indigenous medicine as a diaphoretic (sweat-inducer), diuretic, astringent, emmenagogue (menses-inducer), antirheumatic, and is thought to be effective in nervous and skin diseases. Root and fruit extracts have been shown to produce a depression of the nervous system, and the fruit extract has a blood sugar-lowering action in laboratory animals.

Kusum



Asna

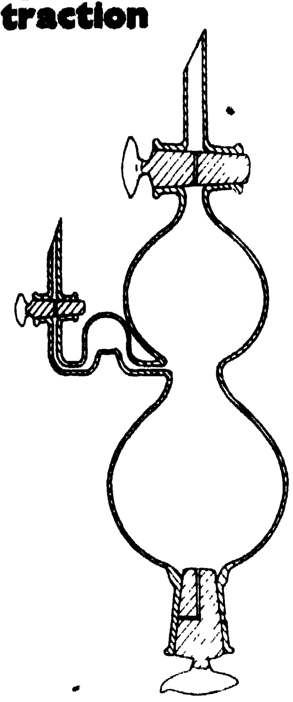
The gum-resin has an analgesi action as well.

Getting to know our indigenou trees, especially those which occur i natural areas, can be a fascinatin endeavour but we may be able t sample only a small fragment of wha nature has to offer For some, th field trip is a relaxing picnic and fo a few it is a rigorous and exactin academic venture. Whatever the ap proach, the beckoning trees are alwa there. Or are they?

S. R. AMLAD

Shisham

Double decking separating funnel simplifies solvent extraction



With this funnel you can strip a solution of its constituents with a heavier or lighter solvent with equal ease, dispensing with the additional operation and equipment normally needed in the latter case. This funnel is useful for day-to-day extraction work in industrial/research and development programmes.

For stripping a solution of its constituent/s with a heavier solvent, a separating funnel can be conveniently used. The separated denser extract is drained off and the original solution is left behind for the second extraction, and so on. But if the extraction is carried out with a lighter solvent, the original solution has first to be drained off into another beaker, followed by the draining of the extract. The drained off solution is returned to the separating funnel for the next extraction. The extraction by the lighter solvent therefore requires additional operations and apparatus. Both types of extraction can be equally conveniently accomplished if a double decking funnel (see figure above) is employed. In its design, one separating funnel has been perched on the other and the drain tube of the upper separating funnel is bent away to one side. With this funnel, the extraction of the constituents by a heavier solvent can be carried out in the usual manner, the denser extract being drained out from the lower drain tube. In case the extraction is carried out by a lighter solvent, the draining of the lighter extract is performed from the side drain tube. The heavier solution in the latter extraction is left behind in the lower portion of the separating funnel for subsequent extraction. Thus, the extraction of the constituents of a solution by the lighter or heavier solvent is carried out equally efficaciously and conveniently.

A small bulb of 1 to 3 cc capacity has been interposed between the narrow central neck and the side drain tube. Any small amount of heavier solution that may inadvertently flow into the side drain tube gets collected in this bulb and returned to the bulk solution by tilting the funnel backwards. The central neck is constricted so that the separation of the upper and lower solutions is clearly marked even in case a small volume of the upper liquid is left in the funnel. It can thus be effectively drained off. The advantage of a double decking separating funnel lies in dispensing with the transference of liquid and pouring it back for further extraction. Additional apparatus is also not required. This funnel would cost Rs. 100 to Rs. 110, compared to Rs. 70 to Rs. 80 for the usual type of funnels.

V. M. BHUCHAR
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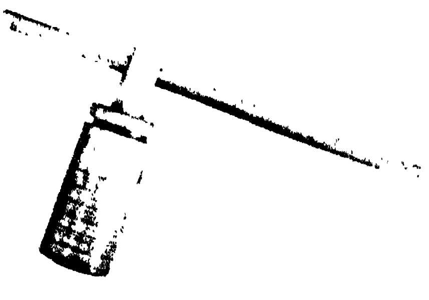
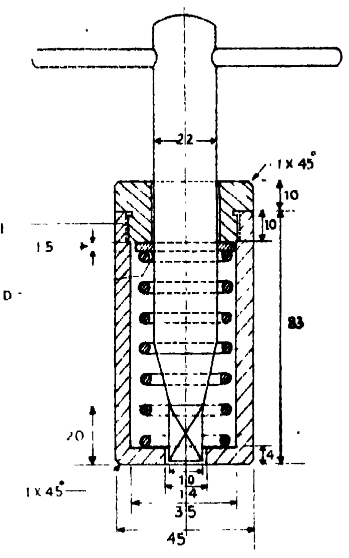
Safety chuck-wrench

This chuck-wrench, developed by Dr. R. L. Murty of Regional Engineering College, Warangal (AP), is designed to eliminate the risk of accidents while operating a lathe.

With the conventional chuck-wrench, used to tighten a three-jaw or four-jaw chuck, which holds the workpiece, accidents often occur when the operator forgets to remove the wrench from the chuck-slot before starting the lathe. Such forgetfulness is quite common among amateur lathe operators and fresh students working in the workshops of academic institutions.





Vertical section of the chuck-wrench. All dimensions in mm.

The mechanism of the safety chuck-wrench is simple (see sketch). Its key is fitted into a cylindrical body containing a spring. The spring presses against a circular projection welded integrally with the key.

To tighten the jaws of the chuck, the key is pushed into the chuck-slot against spring pressure and then manually rotated. And as soon as the tightening is complete and the hand released from the key, it springs out of the chuck-slot of its own accord.

BADIUDDIN KHAN

Silicon-on-sapphire speeds up microprocessors

The key to the advent of microprocessors is the large-scale integration of electronic components like transistors, resistors, etc. The high chip density needed for microprocessors has generally been obtained by the use of some form of MOS technology (metal oxide semiconductor technology, see Science Today, April 1977, p. 19). But MOS devices are inherently slow in operation compared to bipolar devices, which, on the other hand, are power-hungry, bulkier and costly.

Recently, however, Hewlett-Packard of USA has produced a new integrated circuit processor, which offers a combination of low power

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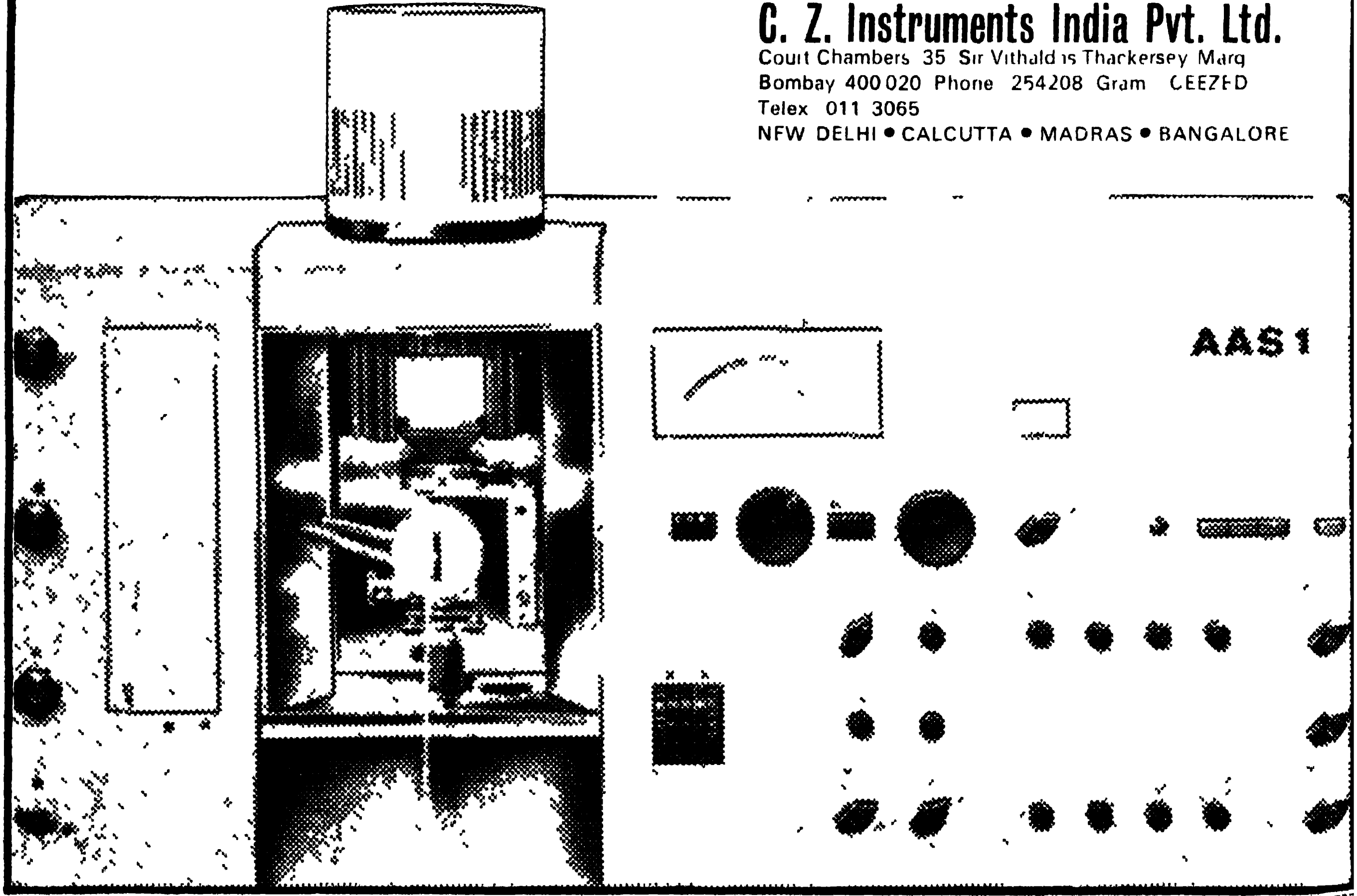

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consumption, high speed, high circuit density and static operation unmatched by other technologies. Based on the silicon-on-sapphire (SOS) technology, this new CPU (central processing unit) chip is a 16-bit unit built with c-MOS ("complementary" metal oxide semiconductor) logic; it compresses 10,000 transistors in a mere 34 sq mm area.

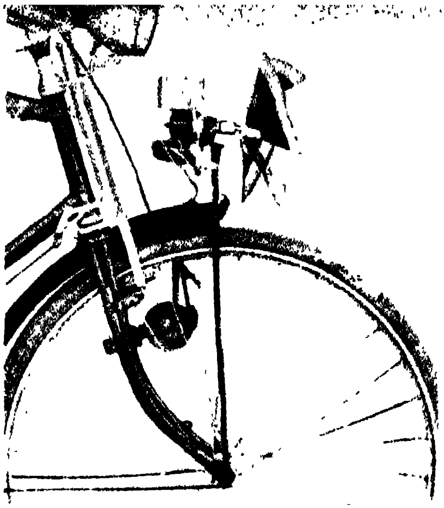
Though the SOS technology first appeared in the market around 1975, because of certain processing problems associated with the technology, only a few devices have been brought out so far. While the circuit is formed in a wafer of bulk silicon material in other integrated circuit technologies, it begins with a thin layer of silicon on a sapphire substrate in the SOS technology. It is this feature that leads to major performance advantages.

The thin layer of silicon (approximately 0·5 micron thick) consists of separate regions in which the isolated diodes and transistors are formed by the ion-implantation process (see Science Today, October 1975, p. 13). Electrical isolation is achieved not by the usual PN junctions; the devices are completely separated by dielectrics — oxide and sapphire. And, for this reason, the isolation is extremely good. The only significant capacitances are between the sources, drains and gates of the transistors. Because the dielectrically isolated devices can be packed close together, largescale integration is possible.

The maximum obtainable operating speed of a circuit is determined by the ability of the available current to charge the capacitance associated with the circuit. The minimised capacitance in the SOS technology makes possible circuit designs with a high speed. The c-MOS/SOS combination presents both N-channel and P-channel MOS field effect transistors on the same substrate and therefore requires N^+ as well as P^+ diffusions for the sources and drains. The use of such complementary circuits enables low-power operation.

A microprocessor based on c-MOS/SOS technology is typically capable of performing 16-bit register-to-register addition in 875 nanoseconds drawing about 350 milliwatts of power. (Comparable values for the popular 8-bit, n-MOS, 8080 processor are two microseconds and 780 milliwatts of power.) While the processors developed by Hewlett-Packard are meant for the firm's electronics products, the c-MOS/SOS technology opens up several advantages that can be exploited in the manufacture of general purpose microprocessors as well.

J. RAJA



Bicycle without dynamo

A simple aero-alternator mounted on a bicycle has been used to produce power for the bicycle lamp. The device could do away with bicycle dynamoes and may be used even on light and powered two-wheelers like mopeds.

The device developed by M. P. Mathews, an engineering student of Bangalore, utilises the air flow across a moving vehicle and converts it into rotary motion. This kinetic energy is used to produce electricity (alternating type), which, in turn, is converted to a DC voltage to charge a nickel cadmium cell. A prototype device developed about 2·5 watts of power at 10 km per hour speed of the bicycle.

The prototype consists of the actual alternator and the storage and stabilisation systems. The whole apparatus weighs only about 4 gm, and may cost not more than Rs. 120. The device would reduce the wear on tyres, pedalling efforts, etc. Besides, it can work even when the vehicle is stationary.

K.P.N.

Emulsions help better combustion

Emulsions have found use in cosmetics, pharmaceuticals, polishes, emulsion paints as well as in leather treatment, textile industry, road construction, metal dispersions, drilling fluids, paper impregnations, insulations, detergents, binders and a host of other applications. An emulsion of two immiscible liquids exhibits properties often quite different from the individual phases constituting the emulsion; it is because of this that emulsions have found such wide applications.

In most of the applications, oil in water (O/W) or water in oil (W/O) dispersions are required — the dispersed phase present in smaller proportion is the first phase, the second phase being the continuous phase. Thermodynamically, the two phases are highly unstable, and as soon as the dispersing forces are removed, largescale coalescence of the dispersed phase occurs, reverting back to the old two phases. One, therefore, requires an emulsifier which is added to the emulsion formulation so as to increase the ease of formulation of the emulsion and/or to give the required stability to the emulsion.

An important recent application of emulsions is in the field of combustion of liquid fuels. For this purpose, water-oil emulsions are atomised and burnt in place of pure liquid fuel. Many advantages are claimed for this. First, the water present gets vaporised, reducing the peak combustion temperature. This, in turn, reduces the formation of oxides of nitrogen which are highly polluting. Second, when water-oil emulsions are used, the effective size of the atomised fuel droplets is very small during combustion. This reduces the excess air requirements for combustion, resulting in better heat economy. Particulate emissions in the form of soot and other carbonaceous matter are also reduced.

The better performance of water-oil emulsions or other emulsions such as methanol-oil containing small traces of water during combustion compared to pure liquid fuel can, in simple terms, be explained by local "microsputtering" of the atomised emulsion particles that takes place in the hot combustion chamber conditions. A very simple example of sputtering is when a small quantity of water is added to a hot oil mass. The already small atomised emulsion droplets get further disintegrated, releasing increased surface area of the liquid fuel for combustion. The resulting cloud of vaporised water phase surrounding the sputtered microparticles of the fuel serve to take away some heat, reducing the peak combustion temperatures.

In metallurgical processes, the injection rates of liquid fuels are very much limited due to many economic and technical reasons. Yet there is always an effort to increase the injection rate. It is reported now that the injection rate can be increased to 1·5 to 2 times over a long period of time if water-oil emulsions are employed. Apart from combustion, some newer applications of emulsions have also been reported in the process industries. Some compositions using water-soluble alkyd resins as emulsifiers have been found to be of great use for adhesives, impregnation and coatings.

S. P. MAHAJAN

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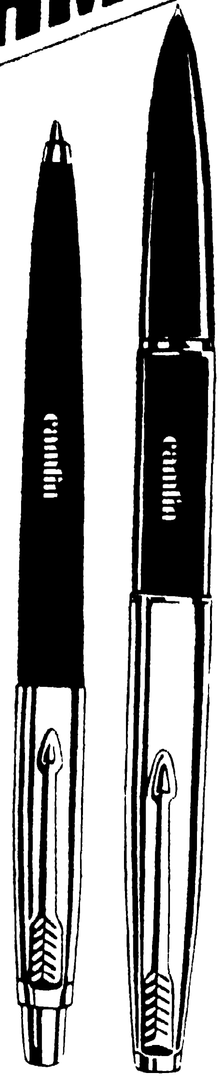

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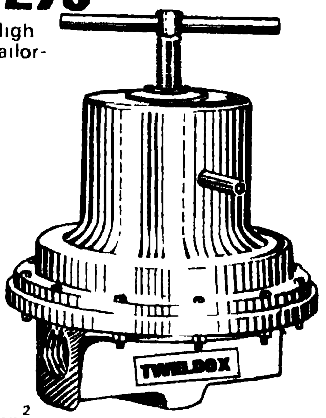
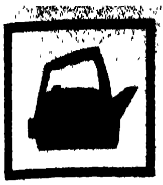
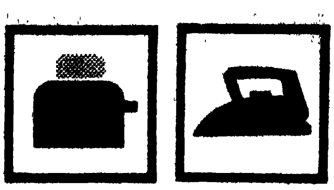




HOW GOOD ARE OUR ELECTRICAL APPLIANCES?



P. J. JOGLEKAR

S. T. PATIL

Pop goes the fuse, when you are in a particular hurry to iron clothes. The electric stove serves a warning, a tingling shock, whenever you touch it. And the water heater is just unmanageable. How often have you thrown up your hands in " shock " or in sheer desperation?

Despite their being in everyday use, electrical gadgets still evoke a sense of fear, particularly when one does not know how an appliance functions. Still more difficult is the behaviour of an electrical appliance under abnormal conditions. Faulty gadgets and installations make the situation worse. And a majority of the domestic electrical installations are faulty.

How can hazards from electrical appliances be avoided? The answer, of course, depends to a large extent on the amount of care that goes into the design and manufacture of the appliances. Though certain standards have been laid down by the Indian Standards Institution (ISI), apparently none of the manufacturers follow them. But the Government proposes to enforce these standards in the future (see box on p. 47). While this measure will protect the consumer to an extent, there are some practical problems in implementing these standards — like the lack of good materials or testing facilities and, above all, the general ignorance about electricity, its hazards and safety requirements. But before we discuss the common defects in the appliances, we must know the domestic installations well and also some of the likely bugs.

A basic electrical installation at the consumer's premises (Fig. 1) consists of a meter, a meter fuse, commonly known as a " cut-out ", a pair of mains fuses, and a mains switch. Before power is supplied to any premises, the wiring of the installation is to be tested by a *licensed* electrician and certified that it conforms to the electricity rules.

A fuse is a device which protects the electrical installation as well as the appliance connected to it against any excessive current resulting from short-circuits or sustained overloads. Normally, an electric current flows through the phase wire to the load (which means any appliance from a bulb to a cooking range) and returns to the supply system via the neutral wire (see Science Today, April 1973, p. 67). If these two wires come in direct contact (Fig. 3), the current takes the shorter route in the circuit (without going through the load), or it forms a " short-circuit ". This results in a very high current, beyond the carrying capacity of the wiring and the meter installed. And in the absence of a fuse, the meter can be damaged and the wiring or the appliances can get burnt. This, in turn, can cause fires. The fuse is so called, because it fuses or burns out when a current much in excess of its capacity flows through it. When the fuse burns out or " blows ", the electric circuit is broken; the current stops flowing, which saves damage to the appliances.

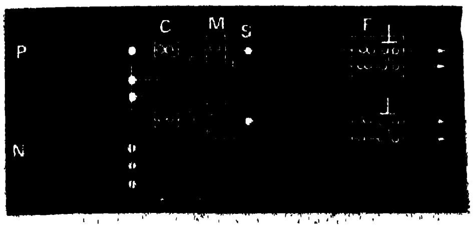
But the point is, the fuse should be rated correctly, that is, it should have the right capacity. Very often, it is not. A fuse, which has a rating lower than the normal load current, will tend to blow off when it should not. This will result in frequent interruptions. A highly overrated fuse, on the other hand, will not fuse when it should, and this is more dangerous. Many electricians use a heavy copper wire for fuse so that it avoids frequent interruptions. If all the fuses in a particular installation are grossly overrated and fail to blow off when they should, an electrical short-circuit can easily cause fire in the wiring. Substandard wiring material for incorrect wiring can aggravate the situation.

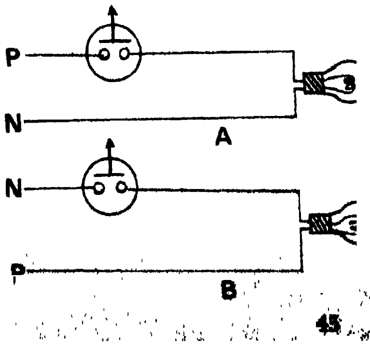
An appliance is connected to the supply through a number of fuses in series — the fuse of the appliance, the fuse in the distribution system, the mains fuse, and the meter fuse. These fuses should have progressively higher ratings; this isolates the overload from the rest of the supply. Thus, if the appliance draws excessive current, its fuse must blow off keeping the supply to other points uninterrupted. Plugs with a built-in fuse are available in the market.

Besides, a good fuse should also distinguish between a transient overload and a continuous overload. Compared to the current they normally draw, many appliances draw a heavy surge current while starting. Consider, for example, a heater using a wire element or a resistance coil for heating. The initial resistance of the element when it is cold is lower than when it is hot. It draws a high current initially which heats the element. As the resistance increases, the current drops so that a steady state is reached. The initial current may be as much as 10 times the final current. Now, if the fuse rating is based on the final current, it may not withstand the initial surge. But if the initial surge current drops sufficiently during the time it takes for the fuse itself to get heated to its melting point, the fuse will remain intact.

Connection of switches is another important point, and another common source of trouble, too. The switch should be in the lead which connects the phase (or the live) terminal of the supply to the appliance (Fig. 2). This excludes the possibility of the live wire being available on the appliance even when the switch is off. If, on the other hand, the switch is connected in the neutral wire, some point on the appliance can have a high voltage and one can get a shock on touching it. While everybody in the

Fig. 1 (below) A basic electrical installation (P = phase wire of supply N=neutral wire C = cut-out M = meter S = supply point F= fuses and main switch). Fig. 2 (right) A. Correct way of connecting a switch. B. Incorrect way of connecting a switch. The switch is OFF in both cases





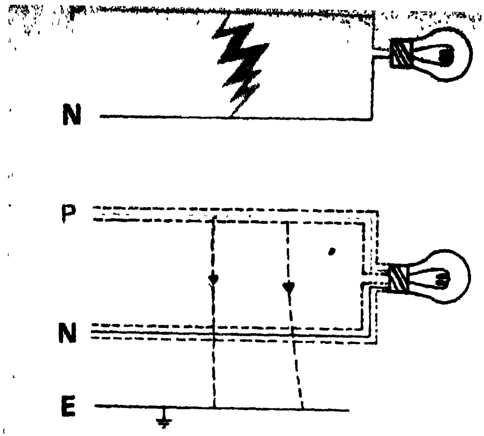


Fig. 3 (top) A short-circuit where the current takes a shorter route. (Above) Leakage current (— Conducting wire, ———— Insulation, ——→ —— Leakage current)

field of electrical engineering knows this point, quite often one comes across switches connected in the neutral lead — because of the negligence and apathy of the electrician, the ignorance of the customer and the connivance of the inspecting authorities.

Two types of electric connections are normally given for domestic use. One for lights and fans, and the other for domestic appliances. The first type is generally rated for 5, 10, or 15 amperes (A) and the latter for 15A or 30A. For higher load requirements, a three-phase supply may be provided. A three-phase supply involves three-phase wires, usually called R, Y and B, and a common neutral wire, N.

The mains voltage for all household supplies is 240 volts (V) alternating current (AC). Even in a three-phase supply, the voltage between each of the phases R, Y, and B and the neutral N is 240V AC and usually all devices or loads are connected between phase and neutral.

Getting a shock

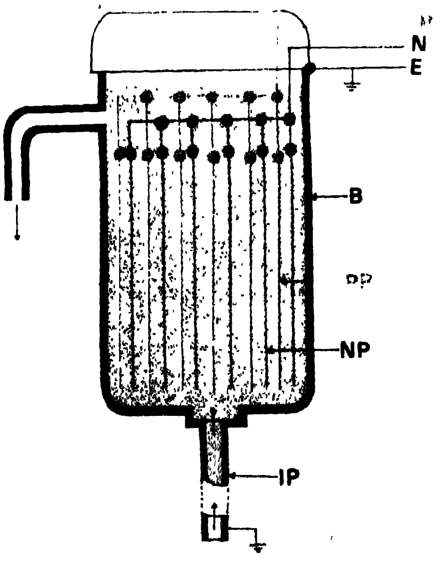
What worries anyone using electricity most is the possibility of getting a shock. There are two such possibilities — either touching a live wire, or touching an appliance or material where there is a leakage current. When one touches either of these, a current flows through one's body to the earth. And even a few milliamperes of current can be fatal (Science Today, August 1971, p. 57).

Good insulation or high resistances increase the total resistance of the appliance or installation which reduces the possibility of a shock. Whenever in doubt, one should, therefore, use some insulating material to handle the appliances or switches. It is best to remove the appliance plug from the socket when shifting it or making adjustments. Though care is taken in the manufacture of an appliance to insulate the live parts so that a live wire does not touch the outer casing of the appliance, this does happen if the insulations break down. The safest thing is to connect the outer casing or the body of the appliance to the earth. This ensures that any leakage current flows safely to the earth. If the live wire inside the appliance touches its body, a short-circuit occurs; the fuse will blow, but there is no danger of a shock since the body of the appliance is earthed.

This is where the use of three-pin plugs becomes important. The third pin provides for the earthing connection. Unlike in the past, the use of two-pin plugs and sockets are now prohibited in new electrical installations.

Good earthing is crucial in the domestic installation. Though this is mandatory, too often electrical contractors fail to provide for this with the connivance of the inspecting authorities. A good earthing can be obtained by digging a pit of about 0·6 m × 0·6 m and 1·2 m in depth (2′ × 2′ and 4′) in which a copper or a galvanised iron rod is hammered deep into the earth. A copper or aluminium wire is connected to this rod, and the pit is filled with charcoal, salt or any other material which increases the conductivity of earth. Ample water is then added to this mixture and the pit is finally filled with earth. The earth wire running in the house is connected to this wire from the earth rod. An alternative method is to connect the earth wire to the water pipe. This is not as satisfactory as the previous method and hence not as safe, either (Fig. 4).

Fig. 4 Plate type instant geyser (P = phase wire N = neutral wire E = earth B = body IP = inlet pipe for water PP = phase plates NP = neutral plate). When power supply is ON and water comes in, the electric current flows from the phase plates to the neutral plates through the water, and the water gets heated directly and quickly. But if scales form on the plates, or they are displaced, the phase plates may come in contact with the body of the geyser. If there is no earth connection on the body, or it is broken, the full supply voltage appearing on the body can give a very severe shock. When the inlet water pipe is non-metallic, the shock can be even fatal. Portion of the current flowing from the phase plates flows to the inlet water pipe and, thus, to the earth. If the installation earth is not good, the leakage current can cause shocks on all the water taps in the premises. This problem can be overcome by the use of geysers with indirectly heated elements, where the water does not come in contact with the electric circuit. Also, if the earth is not good or deteriorated, the use of the water pipe for earth connection can lead to "tingling" shocks and eventually severe shocks



Several of the faults develop from substandard materials. The electrical wiring, for instance, needs to be designed to carry a specified load current; the wiring of a 5-ampere socket should be able to carry 5-amperes current without excessive heating. If poor quality wires, switches and sockets are used, they would not be able to handle the rated current. This leads to excessive heating, and, usually, to a fault. A burnt-out insulation may cause a short-circuit, and if the conducting wire melts, an open-circuit may develop. Loose contact between the plug and the socket causes sparking with consequent heating. The heat is conducted along the wire and the insulation gets damaged. These are external faults, but they are quite significant.

Even the external environment has an effect on the installations. Consider, for example, the effect of humidity. Several materials and objects which may be good insulators when dry do not remain so under damp conditions. Thus, the domestic wiring may not have good insulation during the monsoon, and the danger of getting a shock may lurk at points where normally one would not suspect it. A particularly vulnerable place is the bathroom where even in dry seasons some risk exists because of the water spilling and splashing at various places. And when water is heated, the steam spreads and condenses on various objects, including plug points. Some appliances are also likely to get wet while handling. The connecting cord or the plug of an immersion heater may become wet if it falls in the bucket. Or, an over-enthusiastic lady may wash her cooking range with water which may enter the wiring. All these are possibilities in everyday life. (We shall discuss faults in, and dangers from, specific appliances next month.)

Protective measures

What are the protective measures or devices available against such electrical hazards? The most conventional protection against electrical short-circuits and

The tug-of-war on quality

In May 1976, the Government of India promulgated an order which said that certain domestic electrical appliances and accessories, including switches and plugs, must comply with the relevant Indian Standards Institution (ISI) specifications from November 1976. It prohibited the sale of appliances which fell short on these specifications. The appliance manufacturers, all in the smallscale sector, opposed this move on various grounds. As a result, the implementation of the order was postponed to July 1977. But, in the meantime, further discussions took place and the implementation was put off indefinitely.

While electrical appliance users would naturally welcome Government intervention to ensure quality, the subsequent postponements have blunted the edge of the move. This has happened because the original order was issued hastily without considering the problems in implementing it.

The Government order said that " no person shall himself, or by any person on his behalf, manufacture or store for sale, sell or distribute any household electrical appliances which do not conform to the specified standard ". Neither did the order require the manufacturers to compulsorily subscribe to the ISI Certification Scheme (manufacturers were expected to ensure that the quality of their product conformed to ISI specifications), nor did it specify the inspecting authority responsible for enforcing the order.

Domestic electrical appliance manufacture has been reserved for the small-scale sector. But these small units lack the test facilities needed to check if the performance of a product conforms to ISI specifications. It is surprising that even a big industrial city like Bombay does not have all the test facilities. A test piece has, therefore, to be sent to the National Test House in Calcutta, and it takes several months to get its evaluation reports.

How does a buyer check the quality of a piece of appliance? If all such cases are to be referred to the National Test House, the delay involved would defeat the very purpose of the order.

Another problem the manufacturers face is the procurement of right quality materials and components like insulators, conductors and switches. In most cases, raw material and component suppliers refuse to certify quality. And appliance manufacturers cannot insist because their requirement forms only a small fraction of the component supplier's total business.

It is impossible to bring high quality overnight in a field where there was no quality-consciousness before. A rational and practical programme needs to be worked out to implement the ISI specifications. These standards were formulated in the past when there was no proposal of any compulsory conformation to them from any specific date. Only when it came to their actual implementation did the association of manufacturers of domestic electrical appliances raise a volley of objections. As a result, some of the standards are already being modified.

The Government used ISI specifications as the standard because it was an easy way to define the required quality. The specifications give a complete range of performance criteria and must be viewed as the ultimate goal. However, since it will take indefinitely long to attain it, the present chaotic conditions will continue in the interim period unless intermediate performance standards and deadlines for achieving them are set in a phased programme. For example, the most important aspect is the safety of the appliance under normal use and also under faulty conditions. There have been several instances of fatal accidents caused by electric shocks. Safety requirements must, therefore, be enforced immediately. Other aspects can follow.

The following measures may be a practical solution to the problem of implementing the standards.

1. A separate and independent agency should be set up with complete responsibility to implement the government order for domestic appliances conforming to ISI standards. This could perhaps be on the lines of the Food and Drugs Administration in various states.

2. The specifications may be applied in two, or possibly three, stages. The first phase should insist on adherence to standards on safety of the users and prevention of damage to electrical installations.

3. In every electrical market area, one or two approved test centres should be set up, where any purchaser can get an appliance checked or tested for safety standards at a nominal cost. This will satisfy the buyer and also give basic quality assurance to the trader about the products he is selling.

4. The Government should encourage the opening of independent test laboratories, whose services could be used by appliance manufacturers and distributors. These laboratories should, of course, be approved by the ISI or the Small Industries Service Institute or similar bodies.

The quality of domestic electric appliances and electrical accessories now in the market varies widely. While some products are certainly substandard, some are just acceptable but not up to any standards. Products which are marketed by large companies under their own name are generally made to standards laid down and enforced by these companies. They are an indication of a certain minimum quality to the lay buyer.

The common man is often taken for a ride when he buys a domestic electrical product. Often, the markings on the container or wrapper promise much more than the actual quality of the product. The layman is thus at the mercy of the manufacturers and their distributors. This is where the ISI specifications are expected to safeguard the interests of the consumers, and at the same time help manufacturers improve the quality of their products.

One can, for example, take common items like plugs, sockets, switches, bulb-holders, etc. These are glaring examples of components and products where quality is a casualty. One can buy a 2-pin plug in a price range from 50 paise to Rs. 2. Similarly, there are electric irons costing as little as Rs. 25 each and going as high as Rs. 100. However, one should not be surprised if the handle of a cheap and inferior iron gets hotter than the bottom plate, or if the heating element is burnt out within a few days of usage.

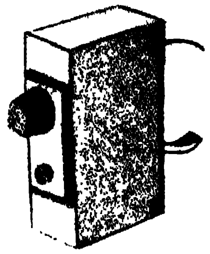
P. J. J.
S. T. P.

sustained overloads is the common fuse, which brings us back to this topic. Since the replacement of the fuse-wire in re-wirable type fuses used commonly in household installations can lead to the use of incorrectly rated fuse-wire, its reliability becomes doubtful. And unless the fuse is placed inside a metal-clad or porcelain case, the arcing or scattering of hot metal wire may spread to adjoining materials which may cause fire.

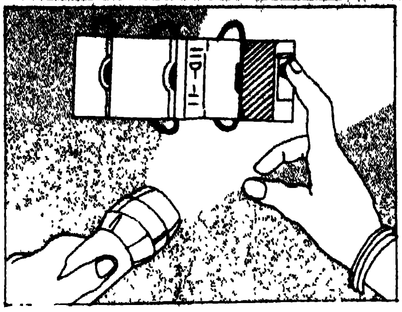
To overcome this risk, the modern practice is to use a miniature circuit breaker (MCB) in place of a fuse. This device (see box on p. 48) is something like a switch; it cuts off the electric supply automatically in the event of a short-circuit or a sustained overload. The advantage is, it can be switched on immediately, since there is no fusing element in the MCB. Neither does one need to call the electrician, nor bother about replacing the fuse-wire. Another advantage is that the rating of an MCB cannot be altered by the user or the electrician. And the MCB can be put ON or OFF manually like a mains switch.

All electrical appliances are generally rated for supply voltage variations of ± 10 per cent of the rated voltage. Within this range, these appliances will work efficiently and without any risk of damage. The Indian Electricity Rules (see box on p. 49), therefore, stipulate that the electricity authorities should maintain the voltage at the supply points

Miniature circuit breakers



The miniature circuit breaker



The miniature circuit breaker (MCB) is a protective device, which can be rated precisely and will operate accurately and reliably every time. The plug-in feature of the MCB makes it versatile. The MCB can be replaced by one with a higher rating without any wiring changes or much interruption. Some of its features are : (1) it functions reliably for years together under normal conditions of use, (2) the rating cannot be altered, (3) it eliminates the risk of fire, as the arc of the short-circuit currents is contained inside the body of the MCB and, moreover, the arc is quenched fast by provision of deion plates, and (4) the inverse time-overload current characteristic (the tripping time is inversely proportional to the square of the current passing through it, or the higher the load, the shorter the tripping time) meets practically the requirements of all the electrical equipments to be protected.

Most of the MCBs operate on the principle that a current flowing through a bimetallic element causes heating therein and hence the deflection of the bimetallic strip. The design is such that the deflection reaches a particular amount within a certain time at a particular overload or excess current. When this happens, the contacts completing the electrical circuit open up and the appliance gets disconnected from the mains supply.

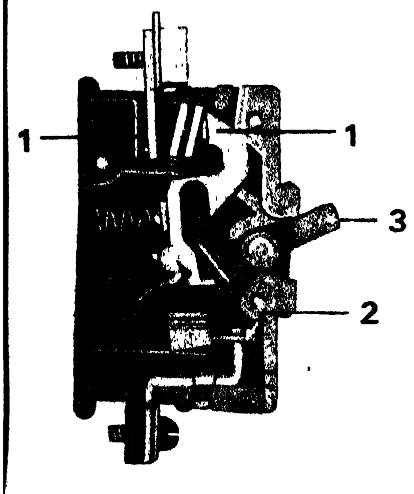
MCBs operating on the hydraulic/magnetic principle are also now available. In this type, the load current passes through a coil in the magnetic field of which a movable core is sealed in a fluid-containing cylinder. The core is spring-loaded; it deflects in proportion to the magnetic field, which, in turn, is proportional to the current in the coil. In short, the deflection of the moving core is proportional to the load current; the time delay is achieved by the travelling time of the core, which is related to the viscosity of the fluid (see fig. below).

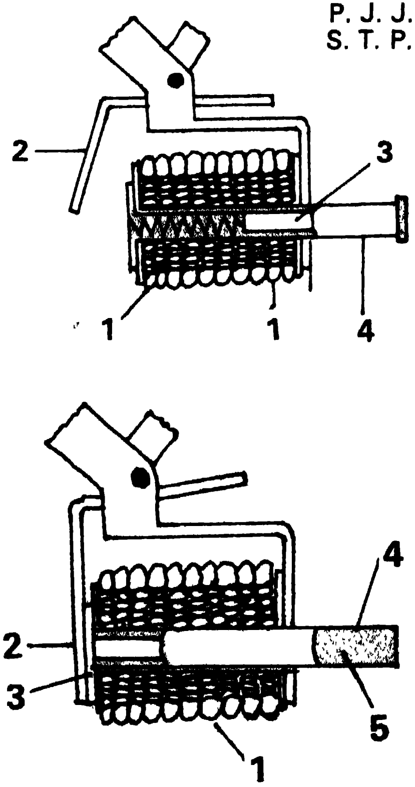
Why haven't MCBs become popular in India? First, the electricity authorities have not shown any awareness about their advantages; the Indian Electrical Rules do not specify their use (see box on p. 49). Second, MCBs cost higher than ordinary fuse-holders and fuses — Rs. 40 to Rs. 50 compared to about Rs. 4 for a fuse-holder and fuse. With increased production, the price may be brought down considerably. But, unless the authorities give an impetus, consumer demand is unlikely to develop.

P. J. J.
S. T. P.

Below. Thermal bimetallic MCB. 1 Contacts 2 Bimetal 3 Operating knob

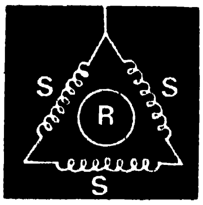
Right. The hydraulic-magnetic MCB. When the load current across the magnetic coil (1) is excessive, the increased flux pulls the movable iron core (3) in the tube (4) containing silicone liquid oil (5). The core attracts the armature lever (2), mechanically coupled to the MCB contacts (right, below), from its normal position (right, top) and the MCB trips





at the consumers' premises within a range of ± 5 per cent and that the supply frequency should not vary by more than ± 3 per cent of the specified frequency of 50 cycles per second.

For a variety of reasons, the authorities find it difficult to maintain the voltage and frequency within these limits all the time. If the supply frequency drops, a device like an electric clock loses time, but if an appliance like a domestic flour mill or a washing machine is used on substantial undervoltage, it will get overheated and may even get burnt. It may appear strange, but motor-operated appliances such as washing machines and fans draw excessive current and get burnt under low supply voltage conditions. The reason is this.



R = rotor
S = stator

In the case of a motor, a substantial part of the applied voltage is used up to overcome the induced or back voltage generated by the motion of the rotor, and the balance is used to overcome the voltage drop due to the flow of load current in the stator winding resistance. When the voltage is low, the rotor fails to rotate; no back voltage is generated and the entire applied voltage appears across the winding resistance causing excessive current. In the absence of a proper protective device like an overload relay or a miniature circuit breaker, this will cause the motor winding to burn. An ordinary fuse hardly provides protection in such cases.

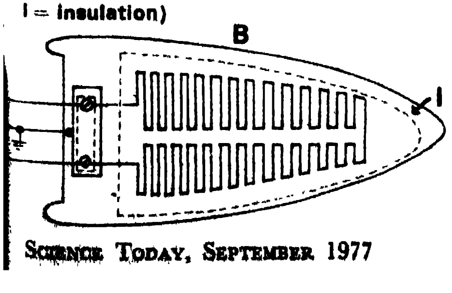
A normal rewirable fuse uses a fuse-wire, which is an alloy of copper, tin and lead. It is the proper combination of these elements, which gives the fuse-wire its rated fusing characteristics. Most of the time, however, strands of plain tinned copper wire are used as fuse-wire, which does not fuse at a particular temperature, nor has a certain time delay in fusing after a large initial current starts flowing through it. A definite correlation is required between this latter property known as " time constant " (the time taken to reach a specified value of the final marked rating of the fuse, the specified value varying according to the appliance) of the fuse and the minimum steady current at which the fusing temperature will be developed in the shortest possible time. As mentioned earlier, the initial current drawn by heating and motor type appliances in cold conditions can be as large as six to ten times the normal steady current. Therefore, to avoid damage due to overheating, the protective gear must operate within a specified time. It is rather difficult to achieve these characteristics in rewirable fuses, while MCBs offer better protection in such events.

In the Western countries, the MCB has replaced the fuse practically in all new installations. In domestic electrical appliances also, the MCB or an equivalent protective gear is finding increasing use to enhance the life of the appliance and save on costly repairs.

The leakage current is relatively small, of the order of only a few milliamperes. It finds its path through the defective insulation or through the appliances and returns through the earth-wire to the ground. The mild tingling sensation one gets sometimes while touching the metal body of an appliance is a result of this leakage current (as the insulation goes on deteriorating, the leakage current increases). The leakage or the shock current being so very small compared to the normal rating of the protective switch gear, the fuse or the MCB is not useful against it. A leakage current causes heating of the leaky parts, and even a leakage of 300 mA can cause electrical fires.

An earth leakage circuit breaker (ELCB) can provide protection against such leakage currents. These are either current-operated or voltage-operated. The current-operated ELCB will operate and disconnect supply when the leakage current exceeds a specified limit. For human protection, the current setting should be below 25 mA, provided the ELCB 'trips' in about 50 milliseconds or less. For merely protecting the installation, 100 mA setting is adequate. The voltage-operated ELCB operates when the voltage on the earth terminal of the appliances or installation being protected exceeds 30 volts.

Fig. 5 If the insulation between the electric circuit and the body of the electric iron deteriorates or breaks down totally, the phase voltage will appear on the body of the iron. If the iron body is properly earthed, the user will not receive a shock, but if the earth is bad, a high earth current can flow, causing the fuse to blow or the MCB to trip (P = phase wire N = neutral E = earth B = body I = insulation)



Protection against leakage current has been made mandatory in many countries, including some in Asia. In Malaysia and Singapore, for instance, ELCBs are required under the electricity rules. No such provision has been made so far in the Indian Electricity Rules. However, the Rules do stipulate that the maximum leakage current in an AC installation should not exceed 1/5,000th of the maximum load current of that installation. For a typical domestic connection of 30A, the maximum permissible leakage works out to 6 mA. In the instant geysers of the plate type (Fig. 4), the electric current passes through the water, which gets heated directly. However, a part of the current finds its way to the earth through the water, and through the metallic inlet pipe connection to the water piping system laid underground. This leakage is far more than what is permissible in the electricity rules. The inspecting authorities are fully aware of this violation of the rules, but are apparently reluctant to take any remedial action. It would be a logical step to ensure the compulsory installation of the ELCBs. Besides protecting consumers, it will also facilitate the job of the inspection authorities when they have to test an electrical installation for good insulation.

Finally, prevention is always better than cure. It would, therefore, be helpful to take some precautions. Some of the basic ones are: (1) fuses of correct rating should be used; (2) all switches should be in the live lead and not in the neutral lead (this can be verified by a neon tester, which will glow even if the switch is off in case the switch is in the neutral lead); (3) the earth lead should be connected to a good earth; (4) the body of an appliance should be invariably connected to the earth; (5) avoid moisture or water getting into the wiring of an appliance; (6) handle the appliances with dry hands and keep the surroundings (like the switchboard and the table on which the appliance is mounted) in a dry condition; (7) never switch on all appliances simultaneously (the total inrush current of all of them would blow the fuse); and (8) when the supply voltage is low and it is necessary to use automatic voltage stabilisers (a device which reduces the large fluctuations in the mains voltage to a narrow range safe for an appliance), to protect costly appliances, each appliance should be connected to a separate stabiliser unit as far as possible. Otherwise the inrush current of one appliance would adversely affect the others through the common stabiliser unit.

The Indian Electricity Rules

The Indian Electricity Rules were framed in 1956 by the Central Electricity Board as required by sub-section (i) of Section 38 of the Indian Electricity Act, 1910 (IX of 1910). These rules cover electrical connections and installations from the mains supply point to the consumer's premises. The rules are amended from time to time to take into acoount the changes in the pattern or increase in the use of electricity in homes, industries as well as in agriculture. They relate to the very high electric power to be carried and the corresponding safety measures required for the efficient and trouble-free use of electricity. The rules have also to keep pace with advances in the design and manufacture of electrical accessories and protective gear, as also the new type of appliances and machines run on electricity. The rules were thus amended in 1969 and in 1973.

Even so, the IE Rules do not mention the use of miniature circuit breakers (MCBs), despite the fact that MCBs are being made in the country for nearly 10 years now. The same is the case with earth leakage relays. With the tremendous use of electricity in modern buildings in big cities and their concentration in high-rise apartments, the complexities of electrical distribution systems have grown rapidly. And yet no provision exists in the IE Rules to take care of electrical fires caused by leakage currents.

Several Western, and some Asian, countries have made the installation of earth leakage relays mandatory. It is time that the authorities in India considered safety requirements arising from leakage currents and introduced relevant measures in the IE Rules.

P. J. J.
S. T. P.

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Mr. Patil (46), an electronics and telecommunications engineer with wide experience in power line carrier systems, is now a consulting engineer in Bombay. He is a member of the Board of Studies for Instrumentation, Pune University, and Board of Studies, Maharashtra, for the diploma course in electrical engineering.

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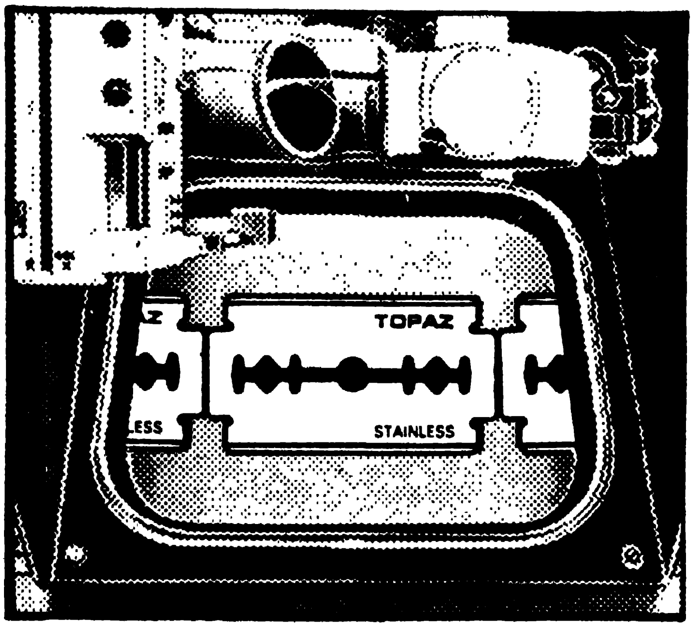

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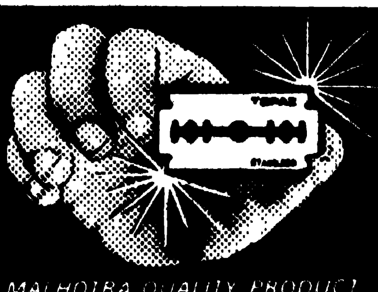

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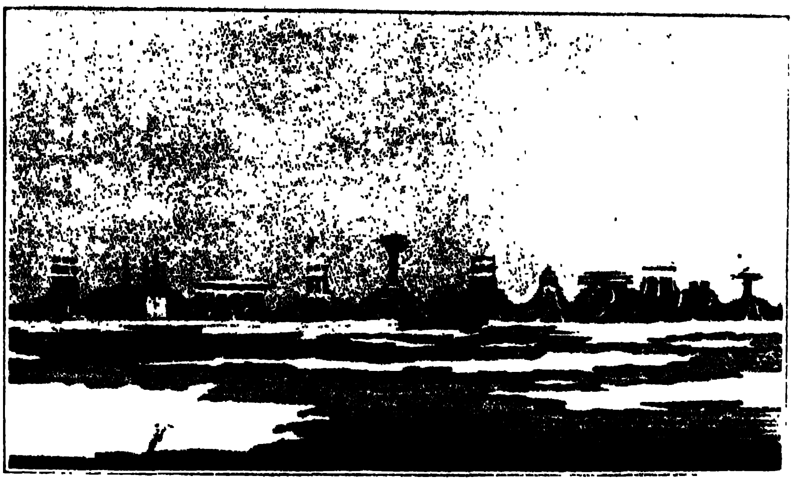


B. D. KELKAR
A. V. DESHINGKAR

Between the Italian mainland and the island of Sicily, lies the strait of Messina. People in Reggio on the Italian shore, looking towards Sicily, may see, on certain days, wondrous castles towering into the sky. Local inhabitants call them the crystal castles of Fata Morgana, or Morgana the Fairy. According to Celtic legends, Morgana was a whimsical fairy, half-sister of King Arthur (of the Round-table), who from time to time chose to exhibit her powers through such mirages. The scientific explanation (or part of it) came after Fata Morgana was detected much more frequently in the northern latitudes as seen in the above picture of the telescopic view of the coast of Greenland at a distance of 60 km.

And the explanation has to do with both reflection and refraction of light. Before we go into these behavioural aspects of light, let's try to understand what light is like.

To be very honest, despite centuries of intense scientific scrutiny, we are still to arrive at a single theory of light. On the one hand, we know light is composed of tiny, irreducible bits of energy — 'quanta' as named by Max Planck, or the more acceptable name 'photon' which Einstein had given to the energy particle of light. On the other hand, it has also been accepted that, these light particles travel in the form of waves — like the waves generated by dropping a pebble in a pond of water.

But this poses a problem. We have all done the experiment in our school laboratory where we placed two cardboards upright on a table, punched holes in each at the same height as that of a candle's flame and when we looked through the hole in the cardboard farthest away from the flame, we could see the light from the candle through the hole in the other cardboard. In other words, we had proved that *light travels in a straight line.*

How do we explain the contradiction? The answer lies in the fact that, although light travels in wave form, the wavelength (the distance between two successive crests or troughs) is extremely short — 0·5 microns or 5/10,000,000 metres — and is not visible to the naked eye. Thus, for all practical purposes, we can say that light travels in a straight line.

The pin-hole camera is based on this principle of straight-line propagation of light (Fig. 2). It's very easy to assemble and will give you lots of fun. (In this article, we shall confine ourselves to constructing toys and experiments that illustrate some of the properties of light, instead of going into their detailed theoretical discussions which, anyway, are given in your text-books.)

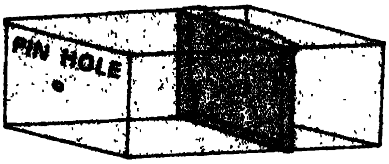


Fig. 2a

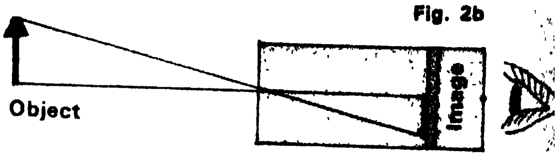


Fig. 2b

PIN-HOLE CAMERA

Take a cardboard box about 10cm × 10cm × 20cm long and make a pin hole using a sharp needle. Paste a thin tracing paper just inside at the other end. Direct the camera towards an object in the sunlight. If you can provide sufficient darkness on the screen (say, by covering with a black cloth), you will be able to see the inverted image of the object.

Why is the image inverted? Fig. 2b shows why by tracing the path of the light rays from the object.

Reflection

All objects reflect light to a certain extent, otherwise we would not be able to recognise the shape, size and colour of them. Now the way in which light is reflected back from a surface is similar to the bouncing back of a rubber ball thrown at a wall: if we throw it straight, the ball will bounce straight back and if we throw it at an angle, it will bounce off at an angle. We know there is a precise scientific "law of reflection": *the angle of incidence equals the angle of reflection and both lie in the same plane.* The simplest way to prove the law is to take a torch and point it to a mirror. As you change the inclination of the incident ray, you will find the reflected ray also changes its inclination by the same angle (Fig. 3).

The law of reflection works in the case of all surfaces, whether smooth like a mirror or rough like a wall. If you shine your

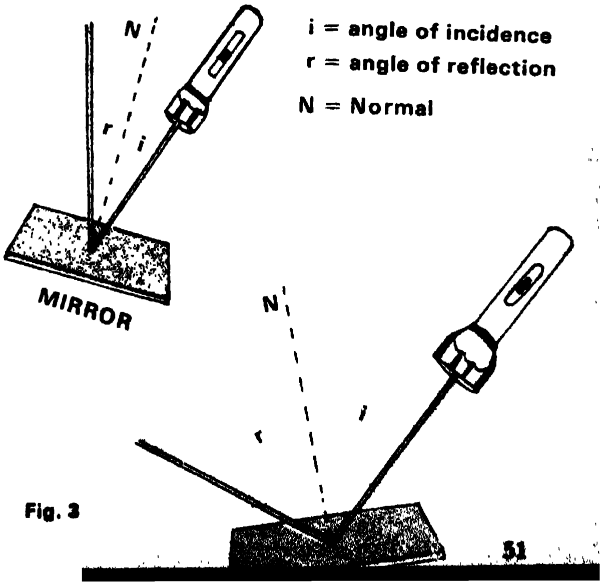


Fig. 3

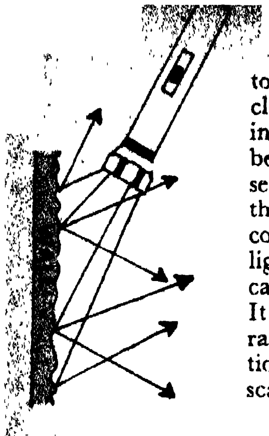


Fig. 4

torch at a wall, you won't get a clear-cut reflection but a scattering of the light. This happens because, light is defracted, that is, sent off in different directions by the uneven surface (Fig. 4). If we could examine each individual light ray, we would find in each case the law of reflection works. It is the combined effect of several rays bouncing in different directions that produces the effect of scattering.

Let's now come back to the mirror. In a plane mirror, the regular reflection of the rays forms an image of the same size and shape of an object. We can construct the image (Fig. 5) by producing two rays from A, one perpendicular to the mirror and the other at some inclination to the normal, to produce rays behind the mirror to get the point A′ - the image of A; similarly, we can get the point B′ corresponding to B.

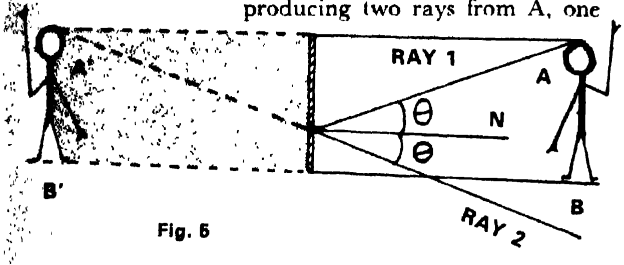


Fig. 5

Now if we compare the image A′B′ with that seen in the pin-hole camera, we see a remarkable difference: in the pin-hole camera, the image was upside down, while in the mirror the image has only changed its right and left: raise your left hand and the image in the mirror is of a raised right hand.

An interesting part of reflection is to get a number of images using a pair of mirrors set at an angle with each other. For example, if the angle between the mirrors is 60°, we can get *five* images (Fig. 6). Actually, there's a mathematical relationship for this: No. of images $= \frac{360^\circ}{\theta} - 1$, where θ is the angle between the mirrors.

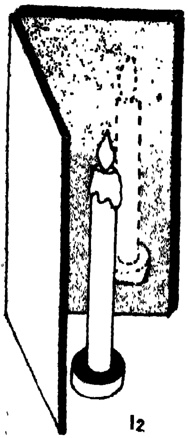
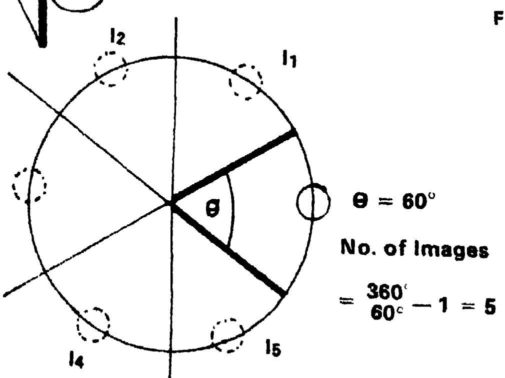


Fig. 6



Suppose we were to place the mirrors exactly parallel and facing each other, and lit a candle in between them, how many images would we get? (Fig. 7). Can you count them? The answer is . . . well, the number of reflected images will be *infinite*.

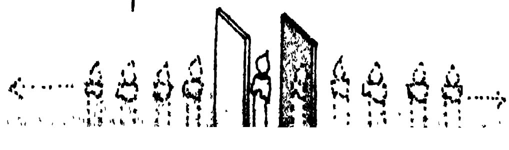


Fig. 7

A simple toy you can make (it is a very common toy sold at fair grounds) is the kaleidoscope that produces beautiful, constantly changing patterns when held against the light. The construction details are shown in Fig. 8.

Mirrors can also be used to make light *turn corners*, as in a periscope. We all know periscopes are used in submarines for viewing ships on the surface of the sea while the submarine itself remains underwater (Fig. 9). In its simplest form, a periscope is a long rectangular box with two openings, one at the top and the other at the bottom (on the opposite side). Facing the top opening is a mirror set at 45° angle At the lower end, facing the viewer, is another mirror set at an angle of 45°. This means the surfaces of the two mirrors face each other and hence anything visible to the top mirror will be reflected down to the bottom one and so to the eye of the viewer. This type of periscope was invented by Johann Hevelius, a German astronomer, in 1687. He had called it a polemoscope (*polemos* means war in Greek) because he thought it would be used by soldiers from inside trenches or from behind parapets without having to raise their heads. Why not make one for yourself? Fig. 9 shows how. Imagine, you won't have to fret standing behind tall men in front of you at a football match or as a parade is passing by.

Coming back to mirrors, you can play a trick on your friends. Everybody expects his image to be reversed left-right in a mirror. Now, if you place two mirrors touching each other at right angles, the image seen at the joint will be a "true" image, that is, left-to-left and right-to-right (Fig. 10). Can you explain how the 'reversal effect' is eliminated? The same effect can be seen with a slightly curved mirror (Fig. 11).

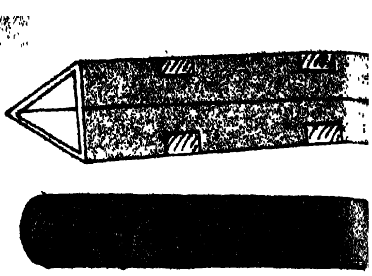
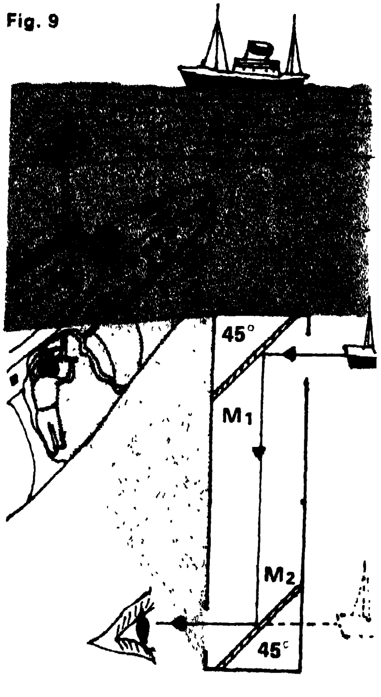


Fig. 8

KALEIDOSCOPE

Take three strips of plain glass (or thin mirror glass) of 3cm x 4cm x 15cm size. Paste them on a black paper and construct a hollow triangular prism as shown. Insert this prism inside a hollow cylindrical cardboard container open at both ends. Take two circular discs of plain glass and put some small pieces of coloured glass bangles between them so that they can move freely between the two discs. Fix these two discs at one end of the cylinder Now, if you hold the tube against light and view through the other end, you can see amazing colourful patterns.

Fig. 9



M_1 & M_2—mirrors (3 cm x 4.25 cr

PERISCOPE

We need a pair of mirrors of 3cm x 4·25cm size. Take a cardboard box of size 3cm x 3cm x 30 (or 40) cm. Fix the mirrors at top and bottom of the box exactly at 45° angle to the axis of the box and facing each other. Cut two circular windows of 2·5 cm diameter in front of each mirror. Hold the box upright and see through the lower window. You will be able to see things above the level of your sight.

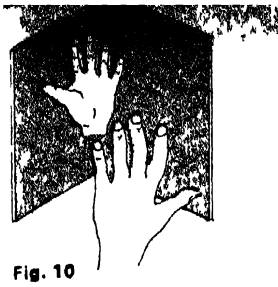


Fig. 10

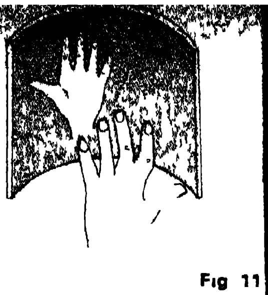


Fig 11

There's a further interesting point to it. Turn the mirrors in Fig 10 or the curved mirror in Fig 11 by 90 The image will promptly turn upside down (Fig 12) something that doesn't happen with one plane mirror no matter how you turn it

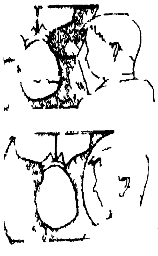


Fig 12

Refraction

Next time you look into a tub of water or a swimming pool, look carefully The bottom will appear to be higher than it actually is Dip a stick into a bucket of water and the portion inside the water will appear slightly bent When light rays pass at an angle from one transparent substance to another, they are bent or *refracted* This happens when the optical densities of the two substances differ, as in air and water — light slows down in its travel through a denser medium Light passing from air to water is slowed down and is bent towards the normal (Fig 13a), light passing from water to air is bent away from the normal (Fig 13b)

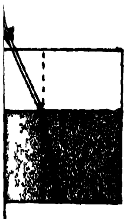


Fig 13a

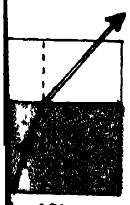


Fig 13b

Now let's try another interesting experiment Take a cork of 4 cm diameter and fix a pin at its centre with one cm of its length sticking out (Fig 14) Pass a thread through the cork and hang the two ends (weighted down) by the side of a tub Now pour water into the tub, up to the level of the cork What do you see now? The pin has disappeared This happens because light rays from the pin do not come out of the water Why not?

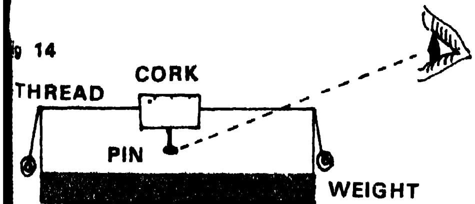
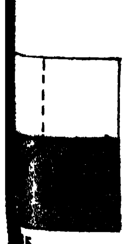


Fig 14

We know the angle of incidence in water is always greater than the angle of refraction in air So, there must be a *critical angle* at which light rays travelling in water will, after refraction, pass directly along the surface (Fig 15)



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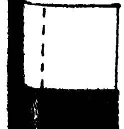
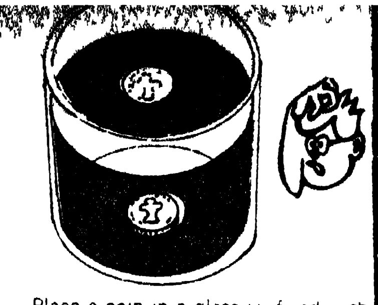


Fig. 16



Place a coin in a glass jar filled with water and if you look from the appropriate angle you can see the coin's image on the surface of the water

Now if you place your palm on the far side of the jar nothing will happen to the image *But if your hand is wet the image will disappear* Can you find out why?

For water, the critical angle is 48 5, for glass 42 When the angle of incidence is greater than the critical angle, the ray does not enter air at all but gets reflected This is known as *total internal reflection* (Fig 16)

Mirages

Mirages were thought to be examples of total internal reflection It usually occurs in deserts or hot road surfaces where a layer of hot air lies immediately above the ground with cooler air above it Light rays from a distant object travel in a straight line through the cool air to the observer's eyes But some of the rays that travel towards the ground touch the surface of separation between the cool and hot air layers and get reflected upwards, if the angle of incidence is greater than the critical angle and reach the observer (Fig 17 This produces the illusion of an inverted tree as if mirrored in a pool of water This is known as 'inferior mirage'

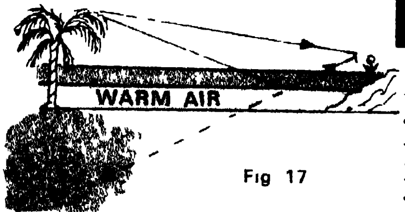


Fig 17

In the sea, one can sometimes see 'superior mirages' like a ship floating in the air Here a thick layer of cooler air lies under a layer of warmer air Light rays from a ship travel upwards and strike the surface of separation and if the angle of incidence is greater than the critical angle, the rays get reflected to the eye of the observer, though the ship may be hidden beyond the horizon (Fig 18)

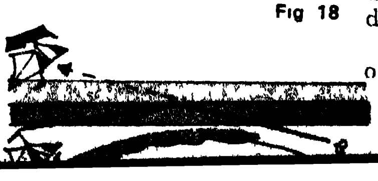


Fig 18

However, some physicists disagree with the above explanation, because they say, the atmosphere can never be sufficiently stratified in nature to produce the necessary discontinuity in density to produce total internal reflections Besides, how do we explain the multiple images sometimes seen in superior mirages (see Fig 19)?

Fig. 19

Here's an alternate explanation given by W J Humphreys in his *Physics of the Air*

Let there be a strong temperature inversion some distance above the surface of the water

AB is the surface of water, CD the undersurface and LF the upper surface of a strong inversion layer GHIKL is the distorted wavefront of light, travelling, as shown, from a distant source (Fig 20)

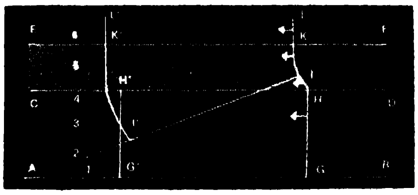


Fig. 20

Now an object from which these wavefronts are proceeding, will look, at 1, upright and no images are seen At 2, confused elevated images appear, in addition to the object itself At 3, the object and two distinct images are seen the lower produced by the segment HI of the wavefront inverted, the other erect At 4, the undersurface of the inversion layer, the inverted image blends with the object and disappears. At 5, only the erect image can be seen, and indeed may be seen when the object itself is below the horizon At 6, the upper surface of the inversion layer, the vertical image merges with the object and disappears

An additional inversion layer obviously might produce other

(Contd on p 63,

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The computer that helped win the War

THE ULTRA SECRET by F. W. Winterbotham, Dell Publishing Co. Inc, New York, 1975, 286 pp, $1·75

There is a somewhat intoxicating air of intrigue about codes and code-breaking that attracts applied mathematicians, and intelligence staff all over the world. Coded messages have a puzzle-like complexity with patterns of information secreted in jumbles of symbols. They also have an underlying quality of regularity because they are meant, after all, to be decoded by someone in a relatively insignificant time.

It is not difficult to devise codes which will take virtually infinite time to crack. For example, a ' one-time ' code (or a code that is used only once, for one message) is still the only safe code as there will never be enough data for the code-breaker to work on. But, for the designated receiver, one-time codes can mean keeping sets of code-books where each page of code is torn off after use. Considering the vast amount of information that is to be exchanged, it would be difficult, especially in wartime, to arrange for enough code-books to be supplied and even more difficult to ensure that they are not lost. Hence cipher machines, which automatically translate a message into its coded equivalent, or vice versa, are regularly used, and the possibility continues to exist of code-breaking successes.

This book is the first report about a British intelligence team which succeeded in cracking *almost all* the high-level codes used by the Germans for wireless transmission in World War II. Like many such efforts, the work began with an adventurous act – that of secretly obtaining from the Polish underground a replica of the Enigma cipher machine used by the Germans. Now the fact that a machine was used for enciphering and deciphering does not mean that its capture automatically allowed all ciphers to be broken. It would be natural for such machines to have ' settings ' (for example, specified positions for numbered wheels, like a safe-lock) and for the actual code to vary with the settings. A set of four wheels, each numbered from 0 to 9, will allow 10,000 different settings (or more than 25 for each day of the year) and a code-breaker could work for years before finding the settings that matched a message. Unless, of course, some electronic machine were to help. And one of the most interesting facts in the book is that the British built, in 1940, what is now known to be the first fixed-program electronic computer and used it for breaking the Enigma ciphers. Very little is known about this computer; the author, who is neither a cryptologist (a cipher expert) nor an engineer, merely describes it as ' the bronze goddess ', but a recent paper indicates that it consisted of 2,500 vacuum tubes. But a breakthrough it was, for it was only several years later that the first wooden electronic computers were built.

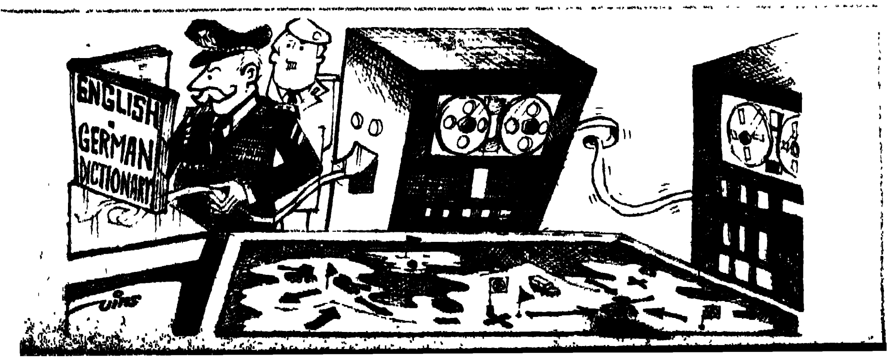
With careful and expert study of the nature of the messages, the idiom used by the senders, and with the assistance of the computer, the British were able to decipher German radio-messages as fast as the Germans could themselves! Even faster, in some cases, as the author describes an occasion where Rommel, in North Africa, asked for his orders to be re-transmitted from Germany; before that was done, the first transmission had been deciphered in England and the information sent on to the Allied commanders. Naturally, the British were careful to use one-time codes in their own transmissions!

The similarity with puzzles goes much further. For example, how could the information that was gathered be used without the Germans guessing that their codes were being broken? In one tragic instance, the British discovered that the Luftwaffe was planning to bomb Coventry: as massive defence of that city could also have indicated the source of the information, it was decided only to secretly alert the civil defence teams and to keep the city's air defence preparations ' normal '. How many lives were lost there and how many saved elsewhere by the ability to continue to monitor German messages, will never be known.

The Ultra Secret is fascinating for the information it offers: vignettes of important figures of the War, facts about the Allied use of the decoded German messages and a picture of Hitler's near-hysteria as the War closed in on him. It is for military historians to re-evaluate the analyses of the Second World War in the light of the revelation that ***practically no*** important Allied action, from 1940 onwards, was taken without the use of decoded German messages. Before major battles, German generals would often send detailed plans and the dispositions of their troops to their staff headquarters (the author comments that this may have been done partly to pre-empt Hitler's predilection to ordering imaginary or unavailable troops into action during the battle). The fact that several Allied generals had such information in advance, and failed to use it, certainly goes against their popular images. For example, Montgomery appears as an over-cautious and stolid commander who never moved into battle unless the odds of men and arms were to his choice.

One other figure who does come through is the author himself who, until the secrecy on it was lifted in 1974, must have brooded over the information which could so drastically change written histories of the War. Even after 30 years, Winterbotham is still the classic RAF man who delights in the manoeuvrings of men in power and with his role in the little world of nicknamed heroes (' Dilly ' Knox, ' Stuffy ' Dowding, and others).

Had the book been written after the War, its lack of analysis could be forgiven but, even after 30 years of retrospect, no trace of political understanding seems to have left its mark on the man who once waded neck-deep through the political upheavals of the period. For him, and for so many others, the War was a question of personalities, strategies and tactics. Still, the facts that he has to spread before his readers are of far greater interest than the shortcomings of the author.



MATHAI JOSEPH

[Dr. Joseph is with the Computer Group at the Tata Institute of Fundamental Research, Bombay.]

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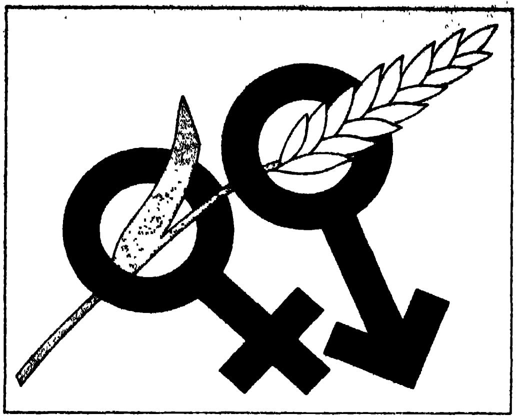
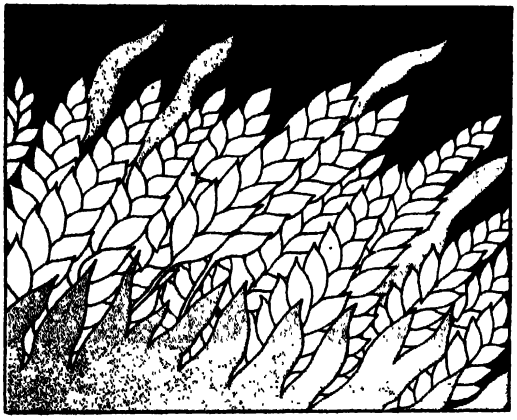


In 1967 a computer experimented with 863,000 possible genetic combinations



And in 1976 the country reaped its fourth successive bumper harvest

In 1967 scientists experimented on a computer with 863,000 possible genetic combinations to develop new plant strains The result of this massive computing exercise was the evolution of new high-yielding hybrid seeds and the green revolution. And more recently, a fourth successive bumper harvest

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All this is part of IBM's continuing commitment to India over the last 25 years To bring new methods and new techniques to bear on the development of the country. Now and in the future.

IBM

What is the difference between an insulator and a dielectric?

It is common knowledge that if one stands on dry wood or wears rubber shoes or slippers and touches a live electric wire, he does not get a severe shock. This, as every school boy knows, is because wood is an insulator. But, what is an insulator? The school text-book says an insulator is a substance that does not pass an electrical current through it. But, there is more to an insulator than meets the eye.

We know that every substance is made up of microscopic atoms. An atom consists of a central nucleus surrounded by orbiting electrons. If we give some external energy to an atom, the electrons of the outermost orbit first get the supplied energy. They then get excited and being loosely bound in the atom, get out of it (if the energy is sufficient) and become ‘ free ’. It is the movement of the free electrons which leads to electrical conductivity. The phenomenon of electrical conductivity was discovered as early as 1728 by Stephen Grey, but the modern explanation came only after the atomic structure was elucidated.

All materials are now classified as conductors, semiconductors and insulators. Insulators are those materials which do not allow flow of charge carriers like electrons through them. They hold charges on their surfaces. In insulators, the outermost electrons are under strain, or, to say, the bond is under tension. The more the bond strength, the more is the material nearer to being a perfect insulator. By applying large amounts of energy, which vary from material to material, the bond can be broken, that is, at high enough energies, all insulators can be made conductors. This energy is known as “ breakdown strength of insulators ”.

However, there is a more advanced picture of insulators than the above “ bond ” picture. It is the band picture and involves a knowledge of semiconductor physics. It is a known fact that an isolated free atom will possess “ discrete ” energy levels. But in a crystal each lattice point (the regular network of fixed points about which atoms and molecules vibrate in a crystal) will experience the energy effects of the neighbouring lattice points. On the assumption that one lattice point contains one atom, only the outermost electrons would be affected. It is found that there exists a band of energies for ‘ coupled ’ atoms instead of separate energy levels as in the single atom. The energies of the outer electrons of any particular atom in a crystal must lie within this band.

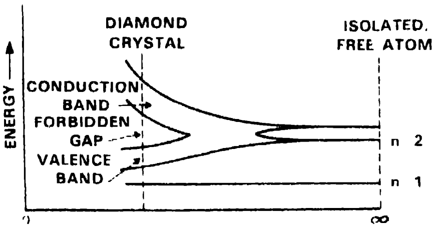


Fig. 1 The electrons of an isolated free atom possess separate energy levels, whereas in a crystal lattice such as diamond, the outer electrons of an atom lie within bands

The width of the band depends on the ‘ coupling ’ between the outer electrons of the atom. There will be a number of bands separated by band gaps in the crystal (Fig. 1). The topmost band with positive energy is called the conduction band. Next to it is the valency band, whose energy is negative, and this is separated from the former by a forbidden energy gap. This gap represents the amount of energy required to rupture or ‘ break ’ the band (Fig. 2). A very narrow band gap (about 0·2 eV; eV is the energy required to raise a single electron through a potential of one Volt) or the overlap of the valency band with the conduction band characterises high conductivity, as usually occurs in metals. Semiconductors (silicon and germanium), out of which modern transistors are made, have a band gap of the order of 0·6 to 0·8 eV. Insulators are characterised by a band gap of the order of 6·0 eV. Usually, the valency band is completely filled and the conduction band is completely empty in insulators (Fig. 3).

But, what is a dielectric? It is also a non-conductor of electricity or, in other words, an insulator, but with a difference. It was Henry Cavendish who first observed that an insulator placed between the plates of a capacitor (a capacitor consists of two parallel metallic plates placed one above the other and connected to a battery or electrical voltage) increased its capacity to store charge for a given voltage (Fig. 4). In the year 1837, Michael Faraday, comparing the ratio of capacity of shell lac filled capacitor to air capacitor remarked: “I cannot resist the conclusion that shell lac does exhibit a case of specific inductive capacity.”

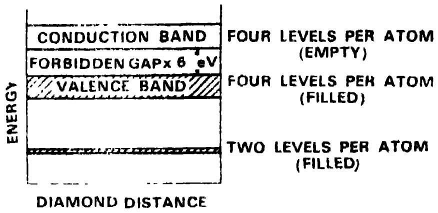
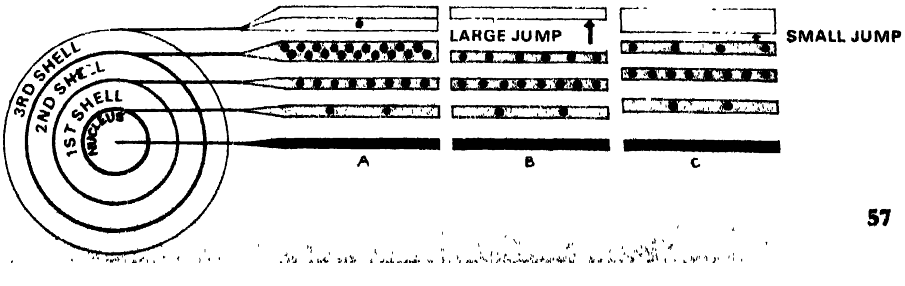

CONDUCTION BAND
FORBIDDEN GAP≈6 eV
VALENCE BAND
ENERGY
FOUR LEVELS PER ATOM (EMPTY)
FOUR LEVELS PER ATOM (FILLED)
TWO LEVELS PER ATOM (FILLED)
DIAMOND DISTANCE

Fig. 2 A diamond crystal consists of a number of bands. The outermost conduction band with positive energy is separated from the valence band below with negative energy by the gap forbidden for electrons

How do we explain the phenomenon of specific inductive capacity? When an electric field is applied to an insulator, it exerts a force on the charged particles (as all matter is composed of charged particles) so that positive charges move in the direction of the field and the negative charges oppositely, resulting in the formation of what are called “ dipoles ”. The charges in a dipole cannot move away with the field, since the Coulombic forces (the forces between the charges) readjust in such a way as to counteract the applied field. Equilibrium is thus attained in the new positions of the charges. The dipoles formed will exert a force which has a tendency for rotation known as “ moment ”. The dipole moment per unit volume

Fig. 3 The electrons in an atom are grouped in shells, each shell representing a particular band of energy level. In a conductor (A) all except the outermost bands are filled with electrons and it requires an energy of only about 0·2 eV to lift the electron from the lower band to the conduction band. In an insulator (B), the conduction band is empty, and it requires energies of the order of 6·0 eV for the electrons in the lower band to reach the conduction band. In a semiconductor (C), too, the conduction band is empty, but the energy required for the jump is only of the order of 0·6 to 0·8 eV



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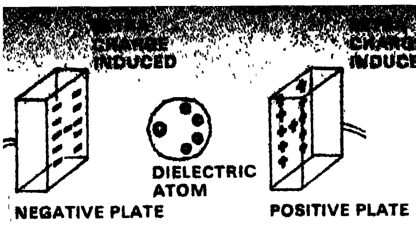


Fig. 4 The charges on a dielectric atom are separated in an electric field. The charged atom then induces more charges on the plates. This increases the capacitance of the capacitor

is known as " polarisation ", a term introduced by Faraday. Because the formation of dipoles is mainly responsible for the phenomenon of specific inductive capacity, these insulators are named as ' dielectrics '. There are certain insulators, for example, biological specimens, which do not form dipoles and, hence, cannot be called dielectrics. So dielectrics are part of insulators. But, nowadays, all non-metals are termed loosely as dielectrics.

A. SUBRAHMANYAM

[Mr. Subrahmanyam is a research scholar in the Department of Physics, IIT, Kharagpur.]

AWARDS & APPOINTMENTS

Awards for inventions

Thirty-six inventors have been given awards by the National Research Development Corporation of India on the Independence Day.

The top honours go to Air-Cdre T. Srinivasan, Group-Capt R. S. Sivaswami, Mr. M. A. Gouthama and Mr. H S. Dhale of Hindustan Aeronautics Ltd (HAL), Bangalore, HAL, Hyderabad, and Bharat Electronics Ltd, Bangalore. They receive Rs. 4,000 for their development of a sophisticated air-borne electronic equipment, details of which are not given.

Five individuals or groups have been awarded Rs. 3,000 each — Mr. Kishor Kothari, Calcutta, for a leakproof rechargeable lead acid battery of 0·9 ampere-hours with a life-cycle of 50 cycles, Mr Gurcharan Singh Bakshi, Central Railway, Jabalpur, for a trolley to monitor railway track defects; Mr. M. S. Viswanathan, Mr. A. B. Prahlad, Mr S. Kalyanasundaram, Mr. S Mohanrangan, Mr. K. Kumar and Mr. H. S. K Murthy of Electronics and Radar Development Establishment (LRDE), Bangalore, for an automatic electronic telephone exchange for the defence services, Mr. V. A Thomas, Mr. Isreal Selvaraj, Mr. R. K. Gupta and Mr N S. R. Chandrasekhar of Indian Space Research Organisation, Bangalore, Mr D. R. Rajanna and Mr. K Narayana of the National Aeronautical Laboratory, Bangalore, for a vertical dynamic balancing machine used for testing the satellite Aryabhata, Dr. Sushil Kumar Basu, Central Mechanical Engineering Research Institute, Durgapur, and Dr. Harijan Bagchi, Mechanical Engineering Research and Development Organisation, Pune, for a magnetic particle clutch.

Those who have been awarded Rs. 2,000 are: Mr. M. Kuppuswamy of the Department of Food, Government of India, for a mechanical paddy drier; Dr. Purushottam Upadhyaya of the All-India Institute of Medical Sciences, New Delhi, for a surgical instrument to correct malformation of the rectum in children; Dr. Harish Chandra Srivastava, of the Ahmedabad Textile Industries Research Association, Ahmedabad, and Dr. Sripad Narhar Harshe, Indore, for a process to make low viscosity tamarind kernel powder to substitute starch for sizing warp in cotton textile processing; Mr. R Thangappan, Dr. H. V. K. Udupa, Mr. B. R. Yadav and Mr. P. Subbiah, Central Electrochemical Research Institute, Karaikudi, for titanium substrate insoluble anodes; Mr P J. Mathews, TELCO, Pune, for a shellcore blowing machine, and Mr. Jitender Pal Mittal and Mr. Bhagwan Singh, G. B. Pant University, Naini Tal, for a mango stone decorticator

Mr. Gopeswar Saha, Hind Refractories, Durgapur, has been awarded Rs 1,000 for a process for rebuilding/repairing broken or damaged refractories Mr Amalendu Bagchi, Central Mining Research Station, Dhanbad, who developed a hydrocarbon vapour detector tube for high boiling petroleum products, receives Rs. 1,000, and so also Mr. Ram Nath Mandal and Mr. Prabir Kumar Dutt, both of Bombay, for a process to produce ketonic resins, and Mr. Ravindra Baburao Marathe, of Miraj, Maharashtra, for a solid state electronic ribbon breaker/anti-patterning device

NCST head

Dr. Atma Ram has been appointed Chairman of the National Committee on Science and Technology (NCST) The newly reconstituted Committee has 26 members, while the earlier committee, under Mr. P. N Haksar, had only 23 members (see SCIENCE TODAY, September 1975, p 65)

Ramachandran heads CSIR

Dr. A Ramachandran, Secretary, Department of Science and Technology, Government of India, has taken over temporary charge as Director-General of the Council of Scientific and Industrial Research He succeeds Dr. Y Nayudamma

TELL US WHY...

. . . the stomach doesn't digest itself?

Though a vegetarian meal is usually lighter, the normal human stomach experiences no problem in processing a mutton chop or a *murgi masala*. Even cannibalism has been known. What keeps the stomach from dissolving itself? The reader will appreciate that the rawness of the meat does not explain away this puzzle.

The two active components of the gastric juice secreted by the stomach are the enzyme pepsin, and the corrosive hydrochloric acid. Pepsin breaks chemical bonds in the protein molecule, decomposing it into simpler molecules Its action on the cells of the stomach wall is not fully understood, so a complete answer to the above question cannot yet be given. But what about the hydrochloric acid?

Once inside the stomach cavity, the acid gets ionised, releasing positively charged hydrogen ions If these ions penetrate the stomach wall, they attack the nerve cells there, stimulating painful muscle contractions and cause damage to the blood capillaries, leading to haemorrhaging — to mention only two of the more recognisable symptoms of 'excess acidity'. Clearly there must be some kind of a barrier to these ions which restricts them to where they are useful.

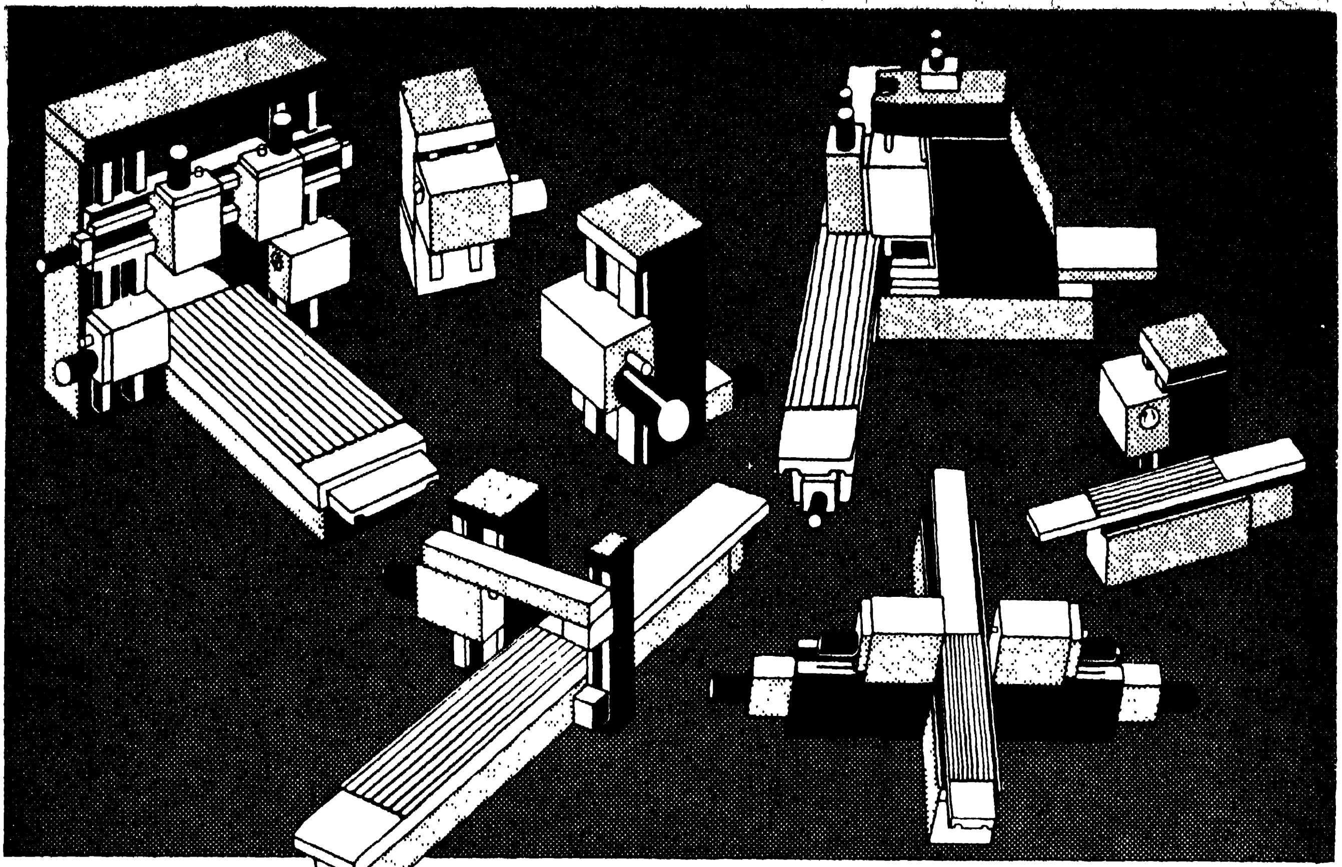
This barrier is provided by the 'epithelial cells' which line the surface of the stomach walls and play the same role as the porcelain lining of chemical reactors The cells are tightly packed in most places, here and there punctured by ducts which bring the gastric juice to the stomach cavity from another set of secreting cells underneath. The outer membrane of the epithelial cells is made up of fatty substances — lipids which are quite impervious to the H^+ ions.

Like any greasy substance, this cell membrane is dissolved by detergents, including the ones used to wash clothes. The bile juice from further down the digestive system also contains detergents like bile salts and 'lecithin' If some of this leaks, or is regurgitated back, it results in the familiar burning sensation as the marauding H^+ ions get past the damaged barrier.

Even in normal digestion, the surface cells undergo some injury. About a million of them are discarded every two minutes and subsequently replaced. The turnover period for the lining as a whole is about three days.

Thus, beyond the esophagus, "no man is a vegetarian". Minor cannibalism takes place, and the stomach slowly dissolves itself. But it does not die, for it's resurrection also proceeds apace, to be completed on the third day.

VIVEK MONTEIRO



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PORTABLE RADIO

This is a very simple portable medium-wave transistor radio. The function of this radio can be divided, for ease of understanding, into five sections.

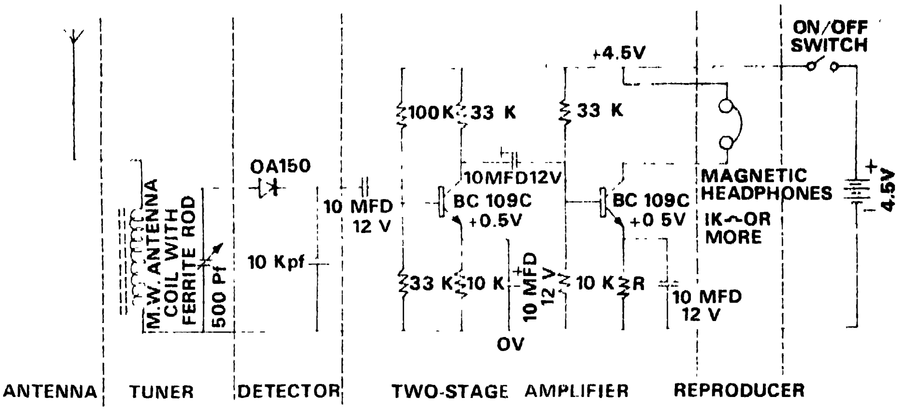
Antenna or aerial: Any metallic wire or measuring steel tape of about a metre length, which can stand straight, can be used as an antenna. A steel tape or a telescopic antenna is preferable because it can be folded when not in use. Very tiny currents of different radio frequencies are induced in the antenna by the radio waves of different transmitting stations. Radio waves are electromagnetic fields in motion and when they cut across an electrical conductor, they induce minute currents in it.

Tuner: The tuner consists of a medium-wave antenna coil wound over a ferrite rod. A variable capacitor is connected across the coil. If the coil consists of two windings, then use the coil with the larger number of turns. This parallel combination of coil and capacitor forms a resonating circuit of a particular radio frequency. By changing the value of the variable capacitor, the resonating frequency of the parallel combination can be changed. This enables you to select the radio waves from any particular transmitting station. Higher and lower radio frequencies of other transmitting stations are bypassed by this tuner section.

Detector: Detection of radio waves, ie, separating the required audio signal from the radio wave, is done by this stage. The diode isolates the audio signals modulated on the radio wave, selected by the tuner section. The capacitor in this stage bypasses the unwanted radio signal.

Amplifier: The two-stage RC coupled amplifier amplifies the weak audio signal provided by the detector stage. At the output of the second amplifier stage, the audio signal is sufficiently amplified so that they can drive magnetic headphones.

Reproducer: The conversion of audio signal into corresponding sound waves is accomplished by causing a diaphragm of the magnetic headphone to vibrate in accordance with the audio signal.



Magnetic headphones, either military surplus or new, are available in the market. If you don't have one of your own, you may buy one having impedance of more than 1K ohms. The higher the impedance, the better it will be. The ohmic value of the resistance in the emitter circuit of the second stage amplifier depends upon the impedance of the headphones. You have to adjust the value of this resistor, denoted by 'R' in the diagram, so that the voltage across it is approximately 0·5V. While choosing the value of R, you may start with 330 ohms ½ watt resistor. Measure the voltage across it while the headphones are in circuit. If the voltage is less, then put different resistors of higher ohmic value in place of 330 ohms, till you get about 0·5 V drop across it The value of R will be between 330 ohms and 3·3 K ohms

The positioning of the M.W coil with respect to the ferrite rod is important. You have to find the position to get the better result. Most often, the coil has to be placed at one end of the ferrite rod.

The portable radio will work best in open space within about 50 km of a medium wave transmitting station. Inside the house, you may have to use an external antenna.

The radio will cost you about Rs. 50·00 without the magnetic headphones

You will need:

Semiconductors Transistors: BC109C, 2 nos.

Diodes · OA150 or OA79 or OA70 or IN34 or IN66, 1 no.

Resistors (½ watt type): 100 K, 1 no.; 33 K, 3 nos.; 10 K, 2 nos.; R, 1 no. (See text).

Capacitors · Electrolytic — 10 mfd, 12 V, 4 nos.

Ceramic or polyester — 10 KpF, 1 no.; Variable — 500 pF, 1 no.

Headphones · Magnetic, impedance 1K ohms or more, 1 no.; Ferrite rod with M W antenna coil, 1 no.

Antenna . telescopic or steel tape, 1 no.

Battery · 1·5 V penlight cells, 3 nos.

Misc ON OFF switch, knobs, battery holder, lug strips or group boards or veroboards, suitable enclosure (non-metallic), wires, solder, screws, etc.

ANIL V. BORKAR

BOOKS *(Contd from p 55)*

Medical endoscopy

A DISCUSSION ON RECENT DEVELOPMENTS IN MEDICAL ENDOSCOPY organised by H. H. Hopkins and D A J. Tyrell, Proceedings of the Royal Society of London, Vol 195, 1977, 227-326 pp, £4·40, overseas £4·55 (Rs. 70)

This volume covers recent developments in gastrointestinal endoscopy (except peritoneoscopy) in four chapters written by leading experts in the field from Europe and the USA. The value of the technique in diagnosing and treating various gastrointestinal problems has been described and its limitations emphasised. The major contribution of upper gastrointestinal endoscopy in establishing the cause of haematemesis and of endoscopic retrograde cholangiopancreatography (ERCP) in differentiating intra- and extra-hepatic jaundice and diagnosing pancreatic diseases are emphasised by several authors.

In the next five chapters, endoneurosurgery (endoscopic intracranial surgery), endoscopy of the palatopharyngeal isthmus, computed tomography and usefulness and limitations of the EMI scanner are described.

The book provides a balanced view of the role of endoscopy in diagnosis. The volume is recommended for libraries, as few specialists will have interest in endoscopy of both gastrointestinal and neurological systems.

H. G. DESAI

[Dr. Desai is with the Department of Gastroenterology, B. Y. L. Nair Charitable Hospital and the Jaslok Hospital and Research Centre, Bombay.]

If after setting up rows of meal trays, pouring the hundredth cup of tea, and sorting out the cheeses and the wines, he can still break the ice for a lonesome passe ...

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You, dear passenger.

AI.9

AIR-INDIA

Science Today, September 1977

BRAIN TEASERS

SWAMIJI'S DEVOTEES : Twelve men and women devotees, men outnumbering women, visited a Swamiji for earning his blessings. The Swamiji distributed 142 flowers among them, giving the same number of flowers to each man. Each woman got two more than each man How many men devotees and how many women devotees were there and how many flowers did each get?

V. A. SHENAI

(Solution next month)

Solutions to last month's Brain Teasers

Three friends:

Since Charan gives Binod and the banker a lift in his car, the banker must be Arun. Arun is not the social worker nor the philanthropist, since he entertains them; so he is the cricketer. The banker is not the grocer and as the teacher gave him a book, he is not the teacher either. Binod is not the philanthropist, since both are office bearers; so, by elimination, Charan is the philanthropist, who is not the social worker, but Binod is. The social worker is not the grocer; hence, he is the teacher, which makes Charan the grocer. The whole set-up is as follows:

Four ailments:

Let us assume that there are only two diseases affecting 70 per cent and 75 per cent, respectively, of the population. When 70 per cent are affected by the first disease, a maximum of 30 per cent (ie, the rest) can have the second disease, in which case the remaining 45 per cent affected by the second disease will also be affected by the first. Thus, at least 45 per cent will have both stomach ailment and cataract. In the same way, with 80 per cent having liver ailment, at least 25 per cent will have all the three diseases. Similarly, with 85 per cent having the fourth disease, at least 10 per cent will have all the four diseases.

	Grocer	Teacher	Social worker	Banker	Philanthropist	Cricketer
Arun	7 ×	6 ×	4 ×	3√	5 ×	8√
Binod	15 ×	16√	14√	1 ×	9 ×	11 ×
Charan	17√	18 ×	13 ×	2 ×	10√	12 ×

(The numbers indicate the sequence of marking; × is for 'no' and √ for 'yes'.)

FOR YOUNG READERS

(Contd. from p. 53)

images, while more or less confused layers might produce multiple and distorted images.

The explanation of Fata Morgana possibly involves a strong inversion over a relatively warm sea. This would create unstable condition, liable to quick and multiform changes. And, such a cool intermediate layer, besides producing a double mirage, acts also as a sort of cylindrical lens that vertically magnifies distant objects seen through it. No wonder the most commonplace cliffs and cottages can get converted through their multiple, distorted and magnified images into magic castles of Morgana the Fairy !

Another spectacular natural phenomenon that has to do with both reflection and refraction of Sunrays is the rainbow. In this very issue (pp. 29-35), you will find a detailed article on rainbows. Read it and you will discover there's a lot more to the rainbow than meets the eye.

Next month, we shall continue with our discussion on light with special emphasis on lenses, and optical illusions. ■

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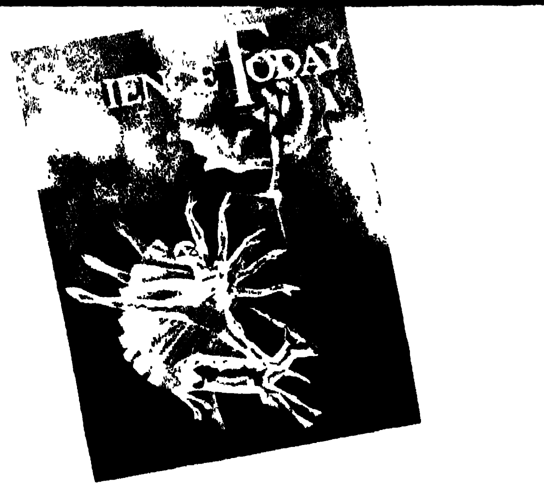

HIGHLIGHTS OF THE NEXT ISSUE

- OF SHAPES & SIZES: WHY THINGS ARE THE WAY THEY ARE
- DIAMONDS
- CROCODILE BREEDING IN INDIA
- HOW TO HANDLE DEFECTS IN ELECTRICAL GADGETS

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(Sd/-) P. J. Lazar, Chirala, Andhra Pradesh

(Photostats of these can be seen at any office of Geoffrey Manners & Co. Ltd.)

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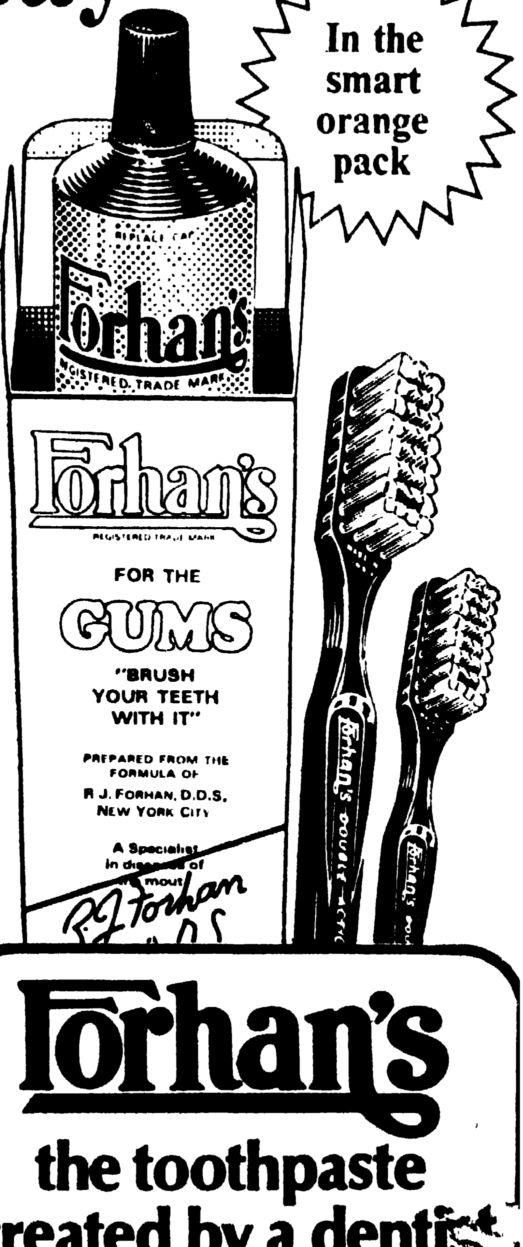


If you have a child who falls ill with alarming regularity, you must read this advertisement. It tells you how to guard your child against water-borne diseases.

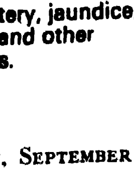
As a parent of a growing child, the first question that comes to mind is: 'How can it be humanly possible?'. How can a child be attacked by water-borne diseases, even after taking the trouble of boiling the drinking water. Yes, it does sound incredible. But sadly enough, it is true. Take for example, this extract from The Times of India dated May 4, 1977: **"Though no figures are available on infant deaths due to water-borne diseases, it is a well-known fact that children in the zero-to-five age-group form 17 per cent of the population, but they account for 40 per cent of the annual deaths."**

Your children are under constant attack!

It is scientifically established that boiling water is insufficient

It's now an established fact that boiling alone is no longer safe. Boiling only kills germs, **but not spores.** You need something that rids you of both. For, spores are the resting stage of bacteria present in water. And even a temperature of 100 degrees C (the boiling point of water) has no real effect on them. A few hours after boiling, they are back in action again, contaminating the freshly boiled water.

Beware of the Matka!



Ask any scientist friend. He'll tell you. Even boiled water stored in matkas is dangerous. For matkas breed germs by the million, in their millions of earthenware pores. Why, even crystal clear water examined under the microscope shows bacteria which cause cholera, typhoid, dysentery, jaundice, gastroenteritis and other terrible diseases.

There must be a solution!

Don't worry! Serious as the problem is, the solution is really simple. Wise parents all over the country have adopted the Puritas Water Filter As you can see in the illustration alongside, the filter consists of two chambers, candles and a tap Water filled in the upper chamber, slowly and safely filters into the lower chamber through the candles.

The secret of the candles

The secret lies in the Puritas Candle, the first of its kind in India. All Puritas Candles are laboratory tested and certified by leading municipal authorities. These candles are made of a very special kind of earth called 'Kieselguhr' which is so precisely porous, it makes the ideal filtering material. In fact, **it filters out all germs and spores, providing you with 100% pure drinking water** in the lower chamber.

Where is the proof that Puritas gives 100% pure water?

We have proof. You are most welcome to come over to any of our offices in India and check photostat copies of actual laboratory test reports. You can also check the originals at our Head Office in Bombay—reports that prove without doubt that the Puritas Water Filter removes bacteria totally. Assuring you of water that is 100% free of germs and spores. 100% safe for your growing children and for you.

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OCTOBER 1977

SCIENCE TODAY

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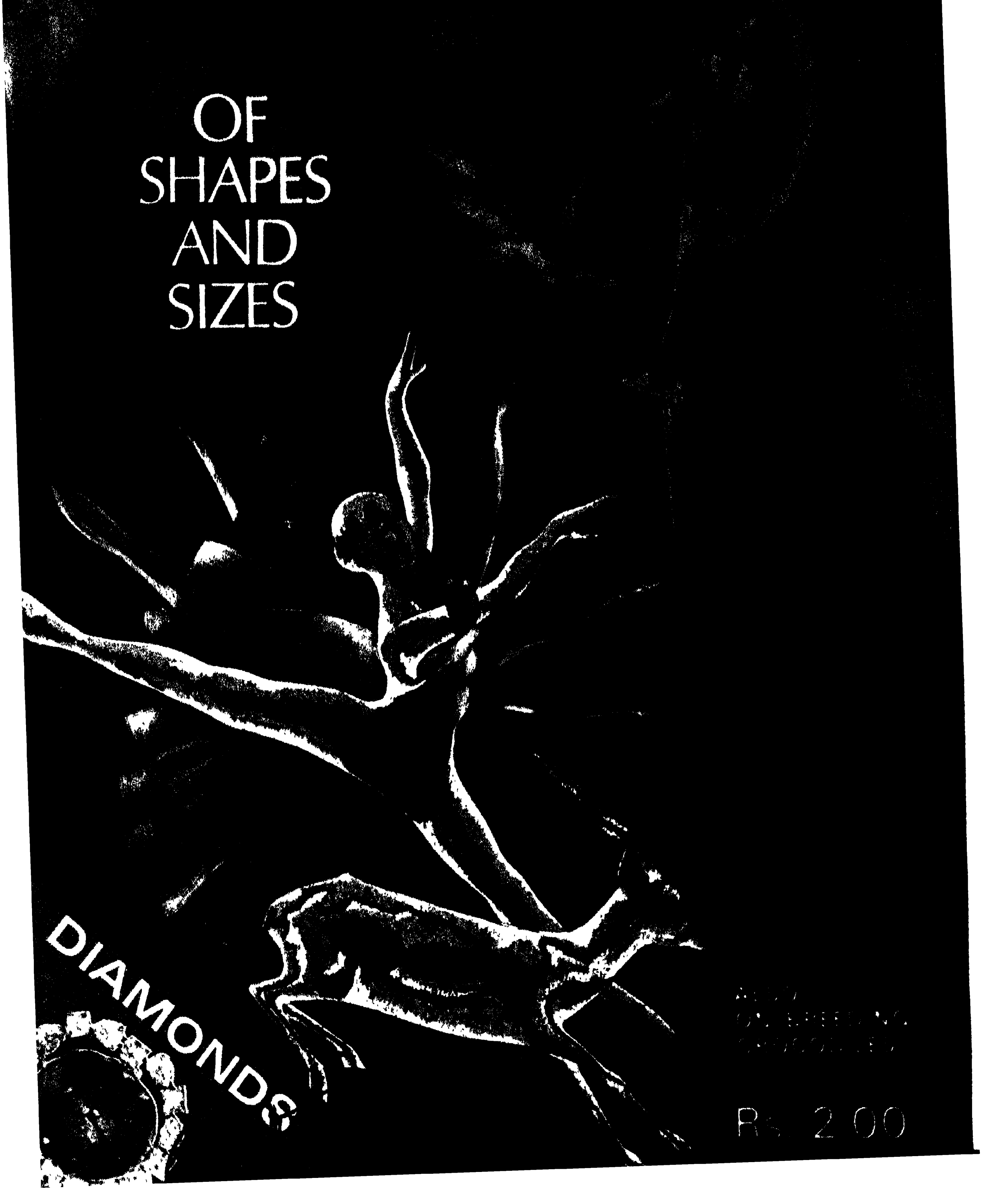

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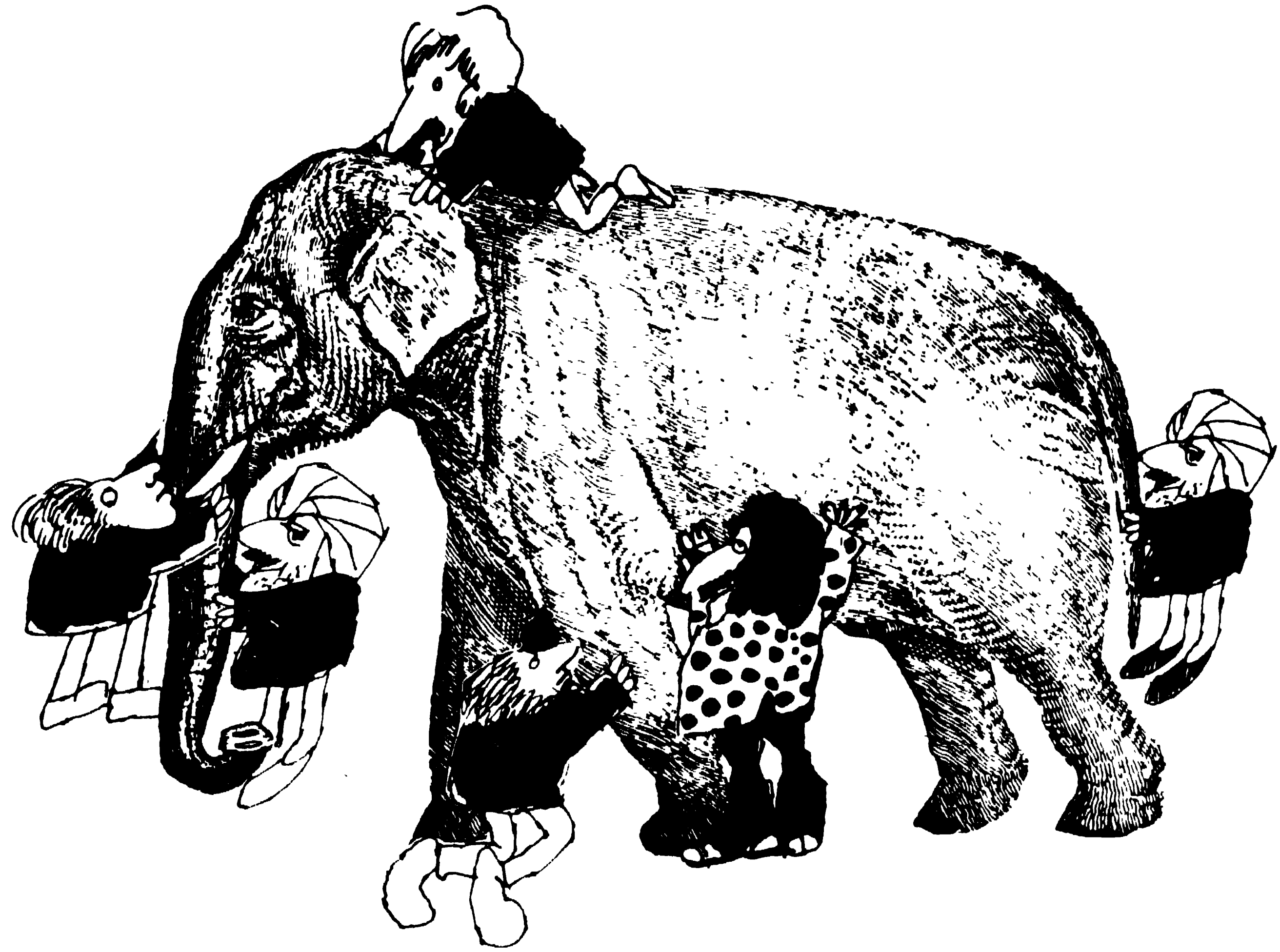

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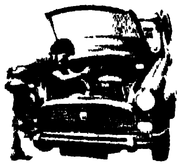

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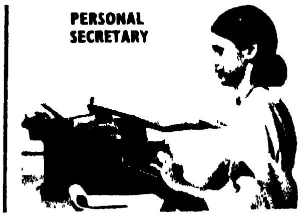

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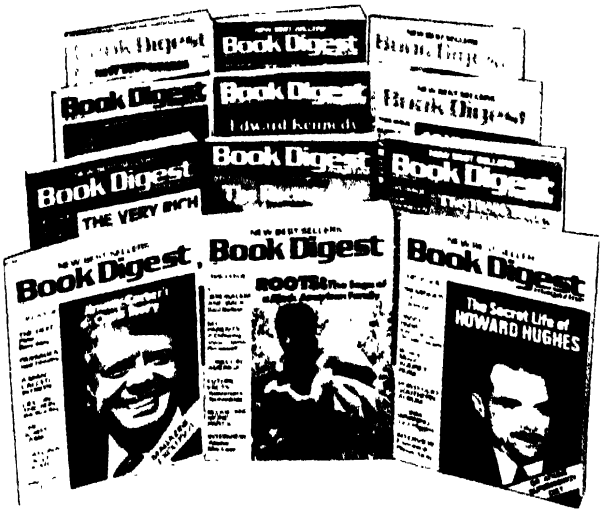

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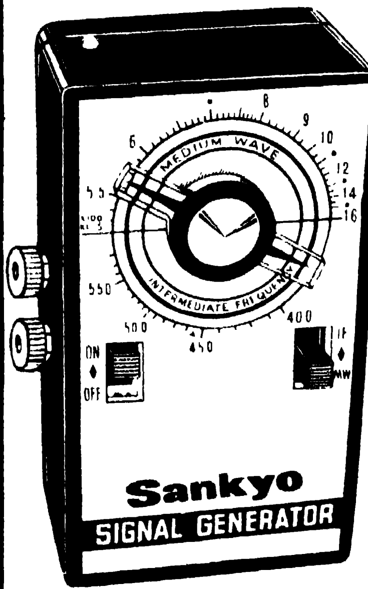

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COVER
Painted by
Nana Shivalkar
(The image at the top is painted from Shaping of the earth by the compasses of God — William Blake s water colour of 1794)

Inset The Hope Diamond (Courtesy Smithsonian Institution)

EDITOR
SURENDR JHA

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A R P Rau

Much of the form of the natural world and the objects in it is a result of the physical forces that have shaped these forms Here s a clue to why things are the way they are

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S R Amladi

This month continuing with our sojourn into deciduous forests now that the season of leaf-fall is near

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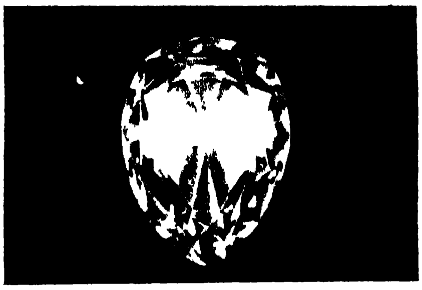
M V Subba Rao

A unique project is on to incubate crocodile eggs and breed the hatchlings in captivity until they can be released in their natural habitats Here s an account of how it is being done in Orissa

36 DIAMONDS

M L Deshpande



Believe it or not the diamond s closest relative is graphite — the black-lead of your pencils Yet what is it that makes the diamond both the king of gems and the monarch of industry ?

46 HOW GOOD ARE OUR ELECTRICAL APPLIANCES?

P J Joglekar & S T Patil

More often it s the heating appliances that make you ask that question How about taking a look at their design and the likely fault areas ? Second article in the series

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B D Kelkar & A V Deshmngkar

This month a trip farther into the world of light — from lenses to the human eye and lots and lots of optical illusions

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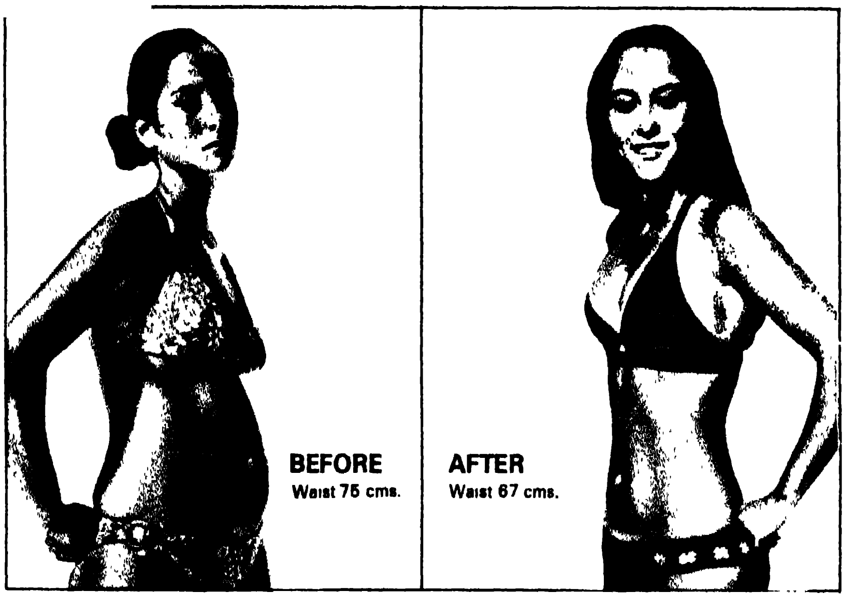
Meet another 'WAISTLINE' winner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OUR GUARANTEE

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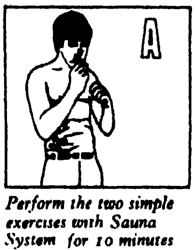

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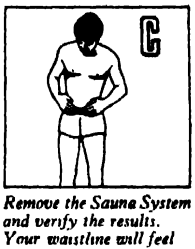

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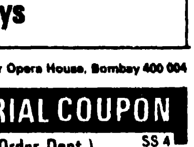

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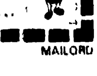

MAILORD

LETTERS

Snakes, sound and the mongoose

" True or false — some beliefs and misbeliefs about venomous snakes " (June 1977) by Dr. N. E. Vad mentions that snakes cannot catch sound vibrations from the air. Recent investigations have proven that the inner ear of snakes responds electrically to airborne sounds and is quite sensitive to a limited range of airborne sounds of 100 to 500 Hz (" The problem of hearing in snakes " by E. G. Wever and J. A. Vernon, *Journal of Auditory Research*, Vol. 1, pp. 77-85, 1960, and *Biology of the Reptilia* ed. Carl Gans, Vol. 4, Acad. Press, New York, 1974). It is, however, still doubtful what role such responses play in the so-called dancing behaviour of snakes.

The question of immunity of mongoose against snake venom is another controversial issue. A number of investigators have suggested that immunity plays an important role in protecting the mongoose from the action of snake venom (*Reptiles* by A.d'A. Bellairs and John Attridge, Hutchinson University Library, London, 4th revised ed, 1975). Moreover, I have seen a mongoose crack the head of a cobra after winning a long and sustained battle. The concept of immunity is further strengthened by the fact that king snakes eat poisonous snakes of other species easily. It is, however, true that poisonous snakes are immune to their own venom. But the non-effectiveness of the venom of other species can only be explained by further immunological knowledge.

SAMAR CHAKRABARTI
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Chinsurah 712101, West Bengal

According to Dr. Vad (" Snake-bite treatment ", p. 50, June 1977), anti venin powder is mixed with distilled water, but I think only water for injection should be used in place of distilled water.

ZAFAR LODI
Instrumentation Ltd
Kota 324005

Dr. Vad writes : **What I presented was a general article and not a technical paper. I had mentioned only about sound vibrations from the charmer's flute. And to this the snake does not respond I have no experience of the airborne sounds of the type mentioned by Samar Chakrabarti. In the case of the mongoose cracking the head of the cobra, so long as the cobra venom does not enter the blood stream of the mongoose, there will be no danger to the mongoose. Even poisonous snakes are not completely immune to their own and to other species' venom. They can tolerate certain quantity of such venoms. If they are experimentally injected with more venom, they cannot stand it and die.**

About Mr. Lodi's point, only the distilled water supplied along with the anti-venin ampoule should be used (which is water for injection) and not ordinary distilled water. Ordinary distilled water may not be pyrogen-free and should not be used for injections.

Some more poisonous plants

I would like to add the following information (" Poisonous plants ", June 1977). Some people take broken seeds of *Nerium odorum* and *Nerium indicum* (' Kaniara ' in Oriya) and family Apocynaceae for suicidal purposes. Vegetative parts and fruits of many members of this family are poisonous.

Heavy doses of opium, obtained from the sap of unripe capsules of the poppy plant, *Papaver somniferum* (Papaveraceae), can cause death in a few hours. Opium contains the alkaloid morphine which, when taken in heavy doses, causes death. Water hemlock (*Cicuta*), poison hemlock (*Conium*), fool's parsley (*Aethusa*), etc of family Umbelliferae possess resins or alkaloids in lethally poisonous quantities when parts (especially the roots and fruits) are eaten

The sap of *Metalia* has been used as an arrow poison. The latex of *Calotropis procera, C. gigantia* (Arka) causes blindness, if it comes in contact with the eyes. Intake of leaves of the above two plants is believed to cause blindness. Some species of *Asclepia* are important livestock poisons. All these plants belong to family Asclepiadeceae.

The contact insecticide pyrethrum is obtained from *Chrysanthemum coccineum* (Compositae). The pollen of rag weed *Ambrocia artemissifolia* is a primary cause of hay-fever. Many members of this family are noxious weeds. The parts of *Aconitum* or monkshood plant (Ranunculaceae) contain strong narcotics which are highly poisonous when eaten.

The foliage and fruits of some members of Coriariaceae are reported to be very poisonous In Mexico, the fruits are used as dog poison. Leaves and roots of *Podophyllum* (Berberidaceae) are poisonous, though the fruits are edible. And several species of noxious weeds are found in the families Conculaceae and Plantaginaceae.

Among fungi, *Amanita phalloides* alone causes 90 to 95 per cent of deaths due to mushroom poisoning in Assam. It can be distinguished from the edible mushroom *Trichloma equeste* only by its characteristic volva, a cup-like remnant of the universal veil at the base of the stalk. But the volva varies from region to region.

Clitocybe and *Inocybe* contain muscarine like *Amanita muscaria* which on eating causes blurred vision, sweating, respiratory trouble, increased peristalsis, reduced heart rate, blood pressure and convulsions. The alkaloid atropine from the *Belladona* plant acts as an antidote in this case.

In the genera *Psilocybe, Palcoleus, Stropharous* and *Conocybe*, the toxin epsilocybin, a hallucinogenic agent, is found. Symptoms appear 15 minutes after consumption of such mushrooms. Poisonous and edible mushrooms look alike in many ways; there is every possibility of mistaking one for the other. Therefore, mushrooms should never be consumed before proper identification.

BANSHEEDHAR MISHRA
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Dist. Cuttack, Orissa 754 103

Aconitum heterophyllum and *Delphinium denudatum*, which have been mentioned as poisonous (" Poisonous plants ", June 1977), are actually non-poisonous plants. *A. heterophyllum*, commonly known as ' Atis ', is among the non-poisonous aconites and is used as anti-periodic, aphrodisiac, astringent and for cough in indigenous systems of medicine. *D. denudatum*, commonly known as " Nirvishi ", is also non-poisonous ; its roots are used as tonic and in tooth ache.

N. C. SHAH
Assistant Research Officer
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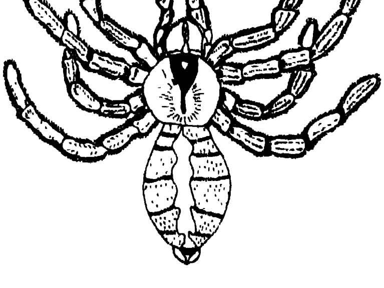
Lucknow

Dr. Viswanathan writes : **The plants *A. heterophyllum* and *D. denudatum* were mentioned as examples of two genera that generally contain toxic principles. It is true that these two species are less poisonous than many other species belonging to these genera. Their use in native medicine does not always mean that they are innocuous, since the dosage of active or toxic ingredient is kept low.**

The poisonous nature of *Aconitum* and *Delphinium* plants is due to the presence of two types of diterpene alkaloids — the highly toxic ester bases like aconitine hydrolysed to C_{19} aminoalcohols and the less toxic derivatives of C_{20} alkamines, like atisine. *A. heterophyllum* and *D. denudatum* contain the less toxic type of alkaloids. There are many plants which contain alkaloids intermediate in toxicity between aconitine and atisine. The roots are generally more poisonous than the other parts of the plants. An interesting account of the use of *Aconitum* plants in arrow poisons has been recently given by Bisset in *Lloydia*, 1976, *39*, 87.

Venomous spiders

On p. 52, the box item " The child-killers," (June 1977) states that " as far as is known, there are no dangerous Arthropods in India " and on p. 55, in " The deadly midgets ", it is given



" spiders can be dangerously venomous, though there are no dangerous species in India."

But in the hilly regions of south India, there is a spider, commonly known as the " giant-hairy spider " or *Poecilotheria*. It is a dangerous and venomous species. Our college is situated close to the hills of the Western Ghats, and we used to see the spiders on trees during the day. We have preserved many spiders in our college museum. In south India, this spider is said to be dangerously venomous , its bite will cause a number of boils with large swellings.

R. DRUSILLA VICTORIA
Asst. Professor in Zoology
Sri Parasakthi College
Courtallam 627802
(Via) Tenkasi, Tamil Nadu

The honey bee, which has on several occasions caused deaths, may be included under " Some stinging insects ". In south India, one can also come across deaths by a species similar to the scorpion, except that it has a needle-like sting instead of a segmented tail. In Tamil, it is called " seethamandalam ".

N. JANARDHANAN
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Panruti, Tamil Nadu

The venomous fishes

Dr. Bhattacharya advises ("Of those deadly denizens of the seas", June 1977, p. 26) that while treating a puncture wound by fish spines, a small incision should be made across the wound and that it should be sucked to draw out the venom. In case the sucker has ulcers in his mouth, will not the venom get into the blood circulation ? What will happen if he swallows the venom ?

P. SHUNMUGA SUNDARAM
21, Chinnakanmoi Street
Tallakulam, Madurai 625 002

Dr. Bhattacharya writes : **Owing to lack of space, it was not possible to give the methods of suction in detail. Suction should be preferably done mechanically by means of a cupping device which consists of a metal or a glass cup and a rubber suction bulb attached to it. However, in case it is sucked directly by mouth, the venom will definitely get into the blood circulation if the person has any ulcer in the mouth ; the result will be the same if, by any means, the venom gets into the blood circulation.**

Recently, Dr. Lazho Baress, a biochemist from Kiel University, West Germany, has managed to extract a few of the toxins that sea anemones contain. He processed 50 kg of sea anemone which yielded approximately 10 grams of a yellowish white powder. This powder had a highly toxic effect on shrimps and fish which form the staple diet of the sea anemone. Experiments showed that about seven-millionths of a gram of this toxin will kill 100 shrimps. The toxin also has a fatal effect on mice and rabbits and scientists, therefore, assume that it will have a similar fatal effect on humans.

It is remarkable that the sea anemone has the same type of neurotoxin found in snakes, scorpions and other unrelated animal species. Snakes are vertebrates, scorpions arthropods, and sea anemones are a lower species of the coelenterate class. Because of this similarity in the chemical structure and physiological effects, sea anemone neurotoxin may be used as a drug in cases where snake toxin is too expensive. Even if it cannot replace cobra venom as a painkiller, it could still prove beneficial to medical research. The fact that the sea anemone already yields two neurotoxins and a number of protein-inhibiting substances which can be used to treat shock indicates that research has entered a promising new stage.

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Coimbatore 641 014

Ootoxins in Schizothoracinae

Dr. B. F. Chhapgar writes (" And some that make deadly dishes," June 1977) that ootoxin is present in Schizothoracine fishes found in Kashmir and Assam. He gives a figure of one such fish ; the legend, states that ' Schizothoracine fishes, a rather poorly known group found in Himalayan foothills, may contain ootoxins '. In fact, in India, a major part of the fishes of this group is found all along the Himalayas and are very well known to ichthyologists. But the figure given by Dr. Chhapgar is actually of a south Indian Schizothoracine fish, *Lepidopygopsis typus* Raj, found in the Periyar Lake, situated far away from the Himalayas. Rather this species is the only exception among Schizothoracinae found in peninsular India. I had opportunities of eating the flesh as well as the ovaries of many kinds of Schizothoracine fishes of the genera *Schizothorax, Schizothoraichthys, Schizopygopsis, Diptychus*, etc occurring in the high altitude areas of the Himalayas but at no time did I feel any toxic effects.

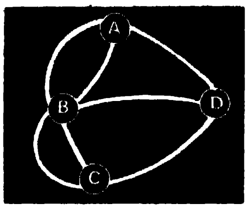
RAJ TILAK
Gulshan Villa
Rajgarh Road
Solan (HP)

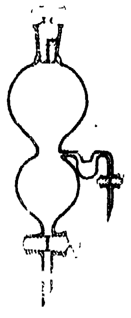
Dr. Chhapgar writes : Raj Tilak is right. **The illustration is that of *Lepidopygopsis typus;* it is adapted from the one in Vol. 43 (1941) of the Records of the Indian Museum from the paper by Sundara Raj on a new genus of Schizothoracine fishes from Travancore.**

Francis Day, writing in Volume 60 of the *Indian Medical Gazette* for 1871, (" On fish as food, or the reputed origin of disease "), has referred to *Schizothorax progastus* McClelland, found in Upper Assam, for its toxicity.

My statement was based on the list prepared by Halstead, (pp. 906, 907) in his *Poisonous and venomous animals of the world* (Vol. 2), 1967, where he includes *Schizothorax planifrons* Heckel from Kashmir, and *S. argentatus* Kessler as well as *S. intermedius* McClelland, both from Central Asia. All these fishes in India are known by the name *loh-one*.

The people in Himachal Pradesh are indeed fortunate in that Schizothoracine fishes there do not show toxicity on consumption.





Above : The route joining regions A and D in the diagram of the City of Konigsberg (" The Four Colour Conjecture ", August 1977, p. 35) was blacked-out in printing.

Right : The drawing of the "Double decking separating funnel" (September 1977, p. 41) was inadvertently printed upside down.— **Ed**

New bullock cart design

Here are a few more suggestions on the bullock cart design (Ideas & Inventions, June 1977).

Though the animals are not burdened with the entire load in a three-wheeled cart, there is another kind of torture — the system of passing a thread through the nostrils of the animal to guide the cart. A lever connected to the front wheel could prove useful in ' manoeuvring ' the cart. Similarly, a simple lever-operated brake could be provided either at the front or the rear wheels.

I suggest axleless independent rear wheels on ballbearings In an automobile, it is necessary that the wheels are coupled with the axle since the driving force, that is, the engine, cannot be coupled separately to each one of them But in the case of a cart, it is not so. The cart as a whole is hauled and hence there is no need to couple the wheels by an axle. Look at the ' tricycle ', for instance. Since the wheels move independently, the system would automatically provide smooth negotiation at curves and steep bends, avoiding skids.

The conventional bullock cart has the big wheels. It would be advantageous if very small wheels with hard-rubber soles (or steel rimmed with pneumatic rubber tyres) were used. This would reduce the risk of road accidents. The cart frame should be completely covered underneath, and also sideways, which provides increased space for goods.

A common design for the yoke is · highly warranted for haulage by one, two or even three bulls.

LAKSHMINARASIMHA RAO
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Ambikanagar 581 363

Vinod Shah memoir

On 5 May 1972, Dr. Vinod H. Shah, agronomist of the Indian Council of Agricultural Research, Delhi, immolated himself to draw attention to the ills that afflict Indian science. A memoir in his name has been published. Scientists interested in getting a complimentary copy may kindly write to the undersigned.

**M. L. KOTHARI
14-B, S. V. Road
Bombay 400 054**

Going downhill on " neutral "

Mr. Rajeev Lochan Sharma's views on saving fuel in downhill driving (Letters, June 1977) betray a lack of information on motor vehicles. Using the engine to slow the vehicle while going downhill is not in any way harmful to the gear-box ; in fact, it is a standard practice. Fuel can be saved by shutting off the fuel supply simply by switching off the ignition if the vehicle is fitted with an electric fuel pump. (Of course, the petrol in the carburettor bowl will certainly go waste. This, however, does not apply to most of the two-wheelers).

That by using the engine and gear-box the vehicle speed will be reduced by a factor unacceptable to the driver is wrong. By shifting down through the gears and switching off, the vehicle can even be brought to a halt. And, as for rolling downhill in neutral with the engine idling, it is very dangerous. It may be alright on gentle slopes, but not on the kind of gradients one gets in hilly areas. In fact, this method is illegal in Britain. Besides the wear and tear on the brake-shoes and drum, prolonged use may heat up the brake-shoes to such an extent that it may lead to a brake-fade. In such an event, one may be lucky to reach home and tell everyone how it happened.

SUDARSHAN KUMAR
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There are some practical problems in using the method suggested by Mr. Sharma. These are : (1) it is illegal to put the vehicle in neutral while descending in some countries , (2) if the speed of the vehicle or the revolutions of the engine are misjudged, one can easily ruin the engine or the transmission system by overriding the synchronisation , (3) in an emergency, the driver is liable to get confused in the selection of the correct gear in a hurry and the result may not be pleasant , and (4) the driver loses the benefit of the braking effect of the engine and, in case of sudden brake-failure or inadequacy, the engine may be damaged, if the speed of the vehicle is misjudged while engaging an intermediate gear.

In fact, the best method to negotiate a downgrade is to roll down in the same gear in which it should have climbed, engine alive and engaged. All motoring guides and manuals suggest this. More information can be found in *The Penguin Car Handbook* by R. Ireson, pp. 167-69 and p. 253.

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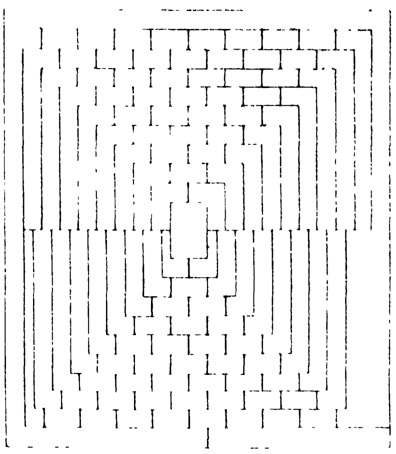
The four colour problem

This refers to the " Four colour conjecture " (August 1977). A couple of years ago *Scientific American* said that two US mathematicians, after experimenting for a number of years with the help of a computer, had come up with a plane figure in which four colours are not adequate. The figure is reproduced below. It looks like it cannot be coloured with only four colours. The readers may try to colour it, and any successful results may be published.



There must be a snag somewhere. Either the four colour theorem stands or there exists at least one plane figure for which four colours are insufficient. It is quite possible that the mathematicians who have proved the theorem have overlooked an error, or it is also possible that the accompanying figure can be coloured with four colours. The issue cannot be considered as closed.

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What awed me most was the reference to Apple and Hakin's 400-page solution of the " Four colour conjecture " which appears fatuous to the untrained eye but which was enough to dumbfound the world's greatest brains for a century. That Apple and Hakin should have included a section in their papers to prove how it is impossible to reduce the number of pages by following their methods is even more fascinating. One wonders, however, why the two scholars did not exclude this section from their thesis, which would have automatically reduced the number of pages and saved them the trouble of proving the irrelevant proposition. But that is how scientists are — quizzical and eccentric — and that is one reason why we admire them.

DEEPANKAR MAITRA
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Can we not go a step further and say that there exists at least one region in a flat map with *four* or less neighbours ? We would then not have to prove the reducibility of the minimal pentachromatic map for the case where a region has five neighbours (which is what Kemp was unable to do).

P. R. REDDY
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Regarding Kemp's argument, I think it is enough if we consider a region surrounded by three adjoining regions. We know that the triangle is the only figure where one side adjoins all the other sides. Any other polygon doesn't do so and a rider adjoins the two nearby sides. Thus the rider of the polygon could be coloured with three colours only. These, and a central colour — that is, four colours will suffice.

D. T. RATHINAM
Chockalinganagar
Madurai 16

Dr. Singhi writes: The figure sent by P. Mohamed (the figure has also been sent by another reader, Job P. Pottayil), was published in *Scientific American,* April 1975, by M. Gardiner in his regular column " Mathematical Puzzles ". Gardiner had received over 1,000 letters on this. No one had caught his "April Fool " joke. In the next issue, Gardiner made it clear that this was just a joke.

Incidentally, I had made it clear in the article that Apple-Hakin's proof of the four colour theorem is only proof for its existence. Given a flat map, four-colouring it may be quite difficult, though theoretically it should be possible in view of Apple-Hakin's result. Mathematicians have also considered the problem of actually producing a colouring of any given map This problem has been proven to be an NP-complete problem. Roughly speaking, this means that there are maps for which producing a colouring may require quite a large amount of time, millions of years, even if one uses computers.

Mr. Reddy asks whether it is possible to prove that any flat map has a region which has four or less adjoining regions. It's not possible ; there are flat maps which have no such regions. One such map may be obtained by drawing a dodecahedron on a sphere or a plane. All its regions are pentangular.

And thanks to Mr. Maitra for admiring scientists so much.

Higher or lower?

Evidence presented in the article " The jumping genes " (June 1977) forces us to agree that some genes in some cases do jump But we don't agree that *Drosophila* is a lower organism (p. 20), because we know for sure that *Drosophila* is a higher organism.

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The second para in column 3, p. 20, should, in fact, read, " The genetic evidence is that in *higher* organisms like *Drosophila* . . . . . .". We did mean that *Drosophila* is a higher organism, as is clear from the previous paragraph where the structural evidence in higher organisms has been presented. The oversight is regretted.—Ed.

Aero-alternator weight

There was an error in the data I had sent you on the aero-alternator (" Bicycle without a dynamo ", Ideas & Inventions, p. 43, September 1977) ; the weight of the contraption is 1.8 kg, and not 4 grams. I regret the error.

M. P. MATHEWS
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- "How a farmer received a pot full of gold!"
- "How another user Teleported a gold jewel box to her, seemingly out of thin air!"
- "How a woman used this method to regain her lost youth!"
- "How a man growing bald, claims he renewed the growth of his hair with this secret!"
- "How a woman used it to bring her mate to her, without asking!"
- "How another woman summoned a man to her, out of thin air!"
- "How a man heard the unspoken thoughts of others, with this secret!"
- "How a woman saw behind walls and over great distances, with it!'
- "How a man broadcasted silent commands that others had to obey!"

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For many years, Jean de Paul dreamed of a way to call upon the invisible forces at work all around us. He spent a lifetime digging and searching for the secret. These investigations brought him knowledge that goes back to the dim recesses of the past.

One day, to his astonishment, he discovered that he could actually broadcast silent commands, which others instantly obeyed. Using the secret he tells you about in this book, he tried it time after time—commanding others to sleep, get up and come to him, talk or not talk—and act according to his silent wishes It worked every time!

Others Obey Silent Commands: Writing of the success of this method, one user reports the following experience :

"I willed her to pick up and eat a biscuit from a plate in a corner of the room She did so I willed her to shake hands with her mother. She rushed to her mother and stroked her hands... ..."

"No one can escape the power of this method," says Mr de Paul.

Hears the thoughts of Others: Experimenting further with the Tele-Photo Transmitter, Jean de Paul soon found that he could 'tune in' and HEAR the unspoken thoughts of others He says, "At first, these hearing impressions startled me, and I took them for actual speech, until I realised that people don't usually say such things aloud! And their lips remained closed"

See Beyond Walls, and Over Great distances: Then he discovered he could pick up actual sights, from behind walls and over great distances! And when he 'tuned in' he could see actual living scenes before him as clear as the picture on a television screen!

Makes Woman appear—seemingly out of thin Air: With mounting excitement, Jean de Paul launched one of the most exciting experiments in the history of psychic research. He wanted to see if the Tele-Photo Transmitter could bring him an actual material object! He chose, for this experiment, the seemingly impossible . an actual living person! He simply focused the Tele-Photo Transmitter, by dialing the object of his desire. In a flash the door burst open, and there—standing before him as real as life—was his long lost cousin!

He stared and rubbed his eyes, and looked again! There—smiling with arms outstretched in greeting—stood living proof of the most astounding discovery of the Century!

DIAL ANY TREASURE!

You'll see how to use the Tele-Photo Transmitter, to summon your desires. This special instrument—your mental equipment — requires no wires, no electricity. "Yet," says Mr de Paul, "it can teleport desires, swiftly from the invisible world." When you dial your desire—whether for riches, love, or secret knowledge—you capture its invisible, photoplasmic form, at which point "it starts to materialize!" says Mr. de Paul.

"Teleresponse Power can work seeming miracles, in your life," says Mr. de Paul. "With it, it is possible to dial any desire—called a Photo-Form—then sit back, relax and watch this powerful secret go to work!"

Instantly your life is changed : With this secret, the mightiest force in the Universe is at your command "Simply ask for anything you want," says Mr de Paul, "whether it be riches, love, fine possessions, power, friends or secret knowledge!" Suppose you had dialed Photo-Form 2 for Jewels, for example That's what Margaret C. did, in an actual example Mr de Paul tells you about. Rich, glittering diamonds and jewels literally appeared at her feet : a pair of gold earings, which she found that morning. a surprise gift of a pearl neckalce, and matching silver bracelets. a beautiful platinum ring set with emeralds and diamonds, dropped on her front lawn!

"Almost overnight," says Mr. de Paul, "It can start to multiply riches, bring romance and love . draw favours, gifts, new friends . or any thing else asked for! It is'nt necessary for you to understand why What is important is that it has already worked for many others men and women in all walks of life ..worked everytime and it will work for you, too!"

The Power of this Method!

You'll see how Jerry D. used this method. He was broke a week before pay day. All he did, he says, was to dial Photo-Form 1 Suddenly he felt a bulge in his pocket Lo and behold! He took out a roll of money .fives, tens, twenties .and more! Obviously, it had been placed there but when? and by whom?

A Brand New Car Comes!

Marty C , a taxi-driver, reports that he just dialed Photo Form 4, sat back, relaxed, and waited for things to happen In a short time, great excitement filled the house His wife came hurrying in, saying, "We won it! We won a car and a cash prize! They just delivered it!" He got up and went to the window There, big and beautiful, standing in the driveway, was a brand new Cadillac!

Brings Mate Without Asking!

Mrs Conrad B., reports that she was tired of 'pursuing' her husband, as she called it. She wanted him to voluntarily do the things she longed for, take her places, show affection But he had'nt looked at her in years. He would fall asleep immediately after supper, or watched the ball games, or read the papers.

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CHECK YOUR NIGHT VISION

Even if you have normal eyesight in daylight, you may be near-sighted in dim light — you may be among the 75 per cent of the population who suffer from twilight — or night-myopia. Which means, you could do with special glasses for night driving.

It has long been assumed that in total darkness our eyes focus at infinity. However, Herschel W. Leibowitz at Pennsylvania State University and D. Alfred Owens, now at the Massachusetts Institute of Technology (USA), have found that this focal distance varies remarkably with the individual — in complete darkness people focus at distances from 30 cm to 3 m, with an average of about 60 cm. Under poor illumination, a subject's point of focus shifts gradually from the appropriate target distance towards the dark focus. Under night driving conditions, the focus is approximately half-way between the two points. Therefore, the shorter a person's dark focus, the greater the night myopia.

Most subjects tested focused at a point no more than 1·8 metres away when driving at night. It follows that more distant objects will appear as a blur. Hence, fast driving at night is apt to be risky for those with night myopia because the identification of forms and shapes, which is the special concern of the central portion of the retina, is seriously handicapped in dim light.

One solution would be to illuminate roads better, say the researchers in *Science* (29 July 1977). Another would be to use special prescription glasses and to screen drivers for night as well as daytime visual performance. In tests with glasses corrected for night-myopia, visual acuity improved by as much as 25 per cent in simulated and real night driving conditions.

TIME DILATATION IN HYPERACTIVE CHILDREN

A study of 100 children, 8 to 12 years old, has shown that for hyperactive children time passes more slowly. Since one of the major problems with such children is their short attention span, particularly in the classroom, this finding could be utilised to increase their attention spans, according to psychological researchers Betty Capella and others of the State University of New York at Buffalo, USA. (*Perceptual and Motor Skills*, June 1977.)

The group, which consisted of 75 normal children and 25 hyperactive children, was asked to press buttons to mark time intervals of 7, 15 and 30 seconds. They were told to press the buttons again when they felt that each of those periods had elapsed. The hyperactives made larger errors of estimation and the longer the time interval, the greater the error. For 30 seconds, normals estimated 26·54 seconds and hyperactives, 50·84.

MISSION TO JUPITER AND SATURN

Voyager 2, the spacecraft launched on 20 August to the giant planets Jupiter and Saturn, is NASA's most far-reaching mission. It is scheduled to reach Jupiter in July 1979. Voyager 1, which has been launched on 6 September, is scheduled to reach Jupiter a few weeks earlier. It will study the Jovian system and then make use of the planet's pull to hurl itself towards Saturn in a slingshot motion. If it completes its Saturn studies, its twin, Voyager 2 will be targeted to fly by Saturn, in August 1981, and go on to Uranus and possibly to Neptune.

Voyager is a departure from previous spacecraft. It lacks the familiar solar panels used to convert solar energy into electrical energy. These would be useless near Jupiter where the solar constant (the energy received by a square centimetre at the Earth's distance from the Sun) would be four per cent that at the Earth's orbit, or at Neptune where it is a mere 0·11 per cent. Hence, the spacecraft uses radioisotope thermoelectric generators (see sketch) carried on a boom to prevent their radiations from reaching the spacecraft.

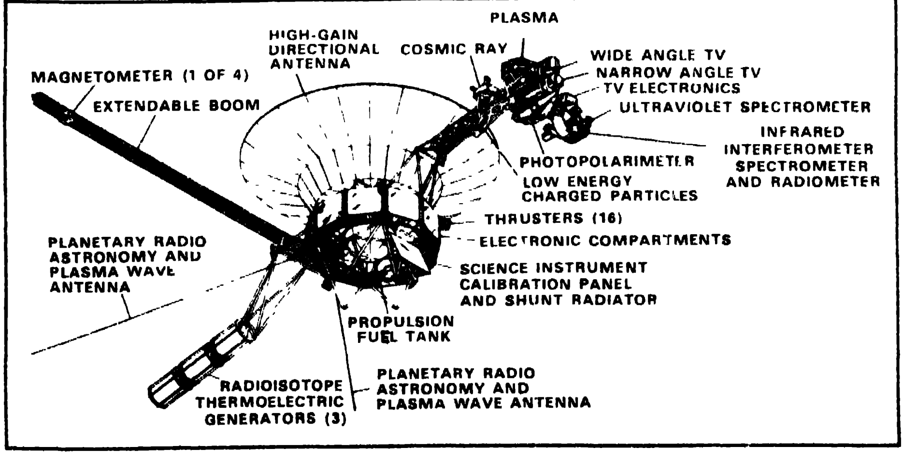
The Voyagers' TV cameras will image the planets and their satellites — which are miniature solar systems — to a detail never obtained before. Other instruments will investigate the unusual particle and magnetic field environments of the planets and the temperatures (from which their internal structure may be inferred). Voyager will pass close to the Jovian satellites, Io, Ganymede and Europa, and determine the interactions of these satellites with the planet's plasma. The 10-metre-long whip antenna will be used with a stepped-up frequency radio receiver to pick up radio emissions from the planet.

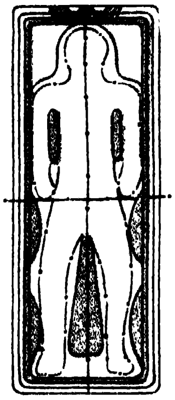
At Saturn the big question will be to confirm the presence of a magnetic field. Voyager 1 will swoop by Titan, a satellite of Saturn larger than Mercury and having (like Ganymede) a substantial atmosphere.

Other instruments are designed to probe the atmospheres of the four planets and their satellites, which together with radio science will greatly increase our understanding of the gaseous outer planets. Planetary atmospheres are important because they tell us how the planets might have formed and evolved.

If Voyager 1 is successful in its Titan encounter, Voyager 2 will be targeted to fly by Saturn in such a way that it can continue on to the planets Uranus and Neptune. A spacecraft can't be targeted to fly close to Titan and also fly to Uranus because the orbits of Titan and Uranus are in different planes. Voyager 2's mission, if successful, will have been the longest space thrust, reaching Uranus in 1886 and Neptune in about 1990

A powerful new tool employed in such a multi-planet mission like Voyager is the reprogramming capability which enables spacecraft operations to be changed to fit the special needs of the different planetary encounters.


PLASMA
HIGH-GAIN DIRECTIONAL ANTENNA
COSMIC RAY
MAGNETOMETER (1 OF 4)
EXTENDABLE BOOM
WIDE ANGLE TV
NARROW ANGLE TV
TV ELECTRONICS
ULTRAVIOLET SPECTROMETER
INFRARED INTERFEROMETER SPECTROMETER AND RADIOMETER
PHOTOPOLARIMETER
LOW ENERGY CHARGED PARTICLES
THRUSTERS (16)
ELECTRONIC COMPARTMENTS
PLANETARY RADIO ASTRONOMY AND PLASMA WAVE ANTENNA
SCIENCE INSTRUMENT CALIBRATION PANEL AND SHUNT RADIATOR
PROPULSION FUEL TANK
RADIOISOTOPE THERMOELECTRIC GENERATORS (3)
PLANETARY RADIO ASTRONOMY AND PLASMA WAVE ANTENNA



REST IN PEACE — UPRIGHT!

Apart from sentiment, there is a sound principle behind the practice of burying a coffin horizontally; if it is up-ended, the corpse will slump to one end. To make things more comfortable for the dead and also to economise on burial space. Alfred Schmitz of Oregon (USA) has patented a coffin for upright burial. Made of plastic, it has three projections inside. Two of these go under the armpits of the corpse and the third under the crotch. These keep the corpse erect when the coffin is lowered feet first into the grave.

Schmitz has thoughtfully provided for he decomposition that will set in. A spring-biased check valve prevents build-up of pressure due to gases and fluids eleased.

A THEORY OF MOTION SICKNESS

Motion sickness — the nausea and vomiting that afflict many people when hey make a sea journey, ride a camel or motor along a tortuous hill road — is not peculiar to man. It occurs in horses, monkeys, sheep, some birds and even codfish. It has long been a puzzle to cientists, because it confers no apparent advantage on the individual, it may even cost the shipwreck survivor on a raft his life. Natural selection should have stepped n to eliminate it at least in those species hat live in trees or in water.

The hypothesis is now put forward by Michel Triesman, Department of Psychoogy, University of Oxford (UK), that motion sickness is a mistaken response by the body to a set of sensory inputs. At every moment of its waking life, particularly during motion, an animal must know its position with reference to ts surroundings. This information comes rom the trunk, the limbs, the semicircular canals of the inner ear and the eyes. There may even be mechanisms for correlating the different types of inputs. When a person is riding a car or a boat, one type of input, for example, from the eye and head, could mismatch another from the trunk), thus affecting the maintenance of head position.

How does this explain the vomiting? Triesman, writing in *Science* (29 July 1977) further hypothesises that vomiting was evolutionarily a method by which animals could get rid of accidentally consumed poisons. Since the systems nvolved in controlling movement are complex and easily liable to disruption, they constitute an ideal warning system or detecting early the effects of toxins because naturally occurring toxins which affect the nervous system are likely to alter sensory inputs which would produce mismatches between the systems. In an animal with unspecialised diet, vomiting or a response to repeat such mismatches would be an advantage. It could also be evolved by a mismatching of the sensory inputs mentioned above.

The evidence for this theory? When the head is held still, the sickness decreases. Also, the disorder is not found when the vestibular system of the ear is destroyed. Infants and puppies are not susceptible to motion sickness, because they are fed on milk or preselected food which is unlikely to be toxic. The subjective aspects of motion sickness, nausea and malaise, are helpful in conditioning the individual to avoid the experience in future.

The theory hangs together all right, but let's wait for experimental confirmation.

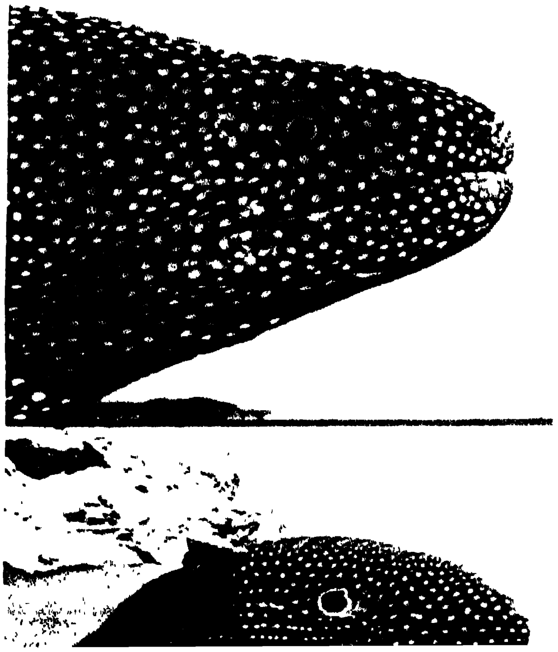
MORE ABOUT THE TUNGUSKA EVENT

Several theories have been advanced about the blazing fireball that hit the valley of the Stony Tunguska river in Siberia on the morning of 30 June 1908, felling trees like matchsticks for up to 30 km around and generating a shock wave that threw nomadic people and their tents high up into the air. The theory that it was a giant iron meteorite, like the one which produced the Arizona meteorite crater in the USA had to be dropped when no crater was found at the site. An alternative theory is that the event was caused by the explosion of a nuclear-powered spaceship. Comparison of old seismograms of the Tunguska event with modern nuclear air explosions suggest that it must have exploded with a force of 12·5 megatons at an altitude of 8·5 km, but measurements of trees at the site have shown no traces of abnormal radioactivity. However, the rings of two trees, one near Los Angeles and the other near Tucson (USA), showed a

FALSE EYE THAT FOOLS THE FOE

How a 15 cm fish fools predators by mimicking a metre-long noxious moray eel is revealed by a study conducted by John E. McCosker of the California Academy of Sciences (USA).

The fish (*Calloplesiops altivelis*) lives in coral reefs at between four and 30 metres depth; its model, the eel (*Gymnothorax meleagris*) also lives in coral reefs at one to 30 m depth and is found within the range of the former. Mimic and model are similar in coloration, having a dark brown to black background overlaid by numerous white to bluish spots smaller than the eye in size. The mimic also has an eyespot located along the base of the dorsal fin which simulates the eye of the model. When threatened by a predator, *Calloplesiops* expands its normally relaxed fins to make the eyespot fully visible, remaining near the opening of its refuge with the hind portion of its body left exposed. In doing so, *Calloplesiops* presumably appears to a predator to be a *Gymnothorax* which when encountered by scuba divers retreats into the reef, leaving its head and front regions exposed. Presumably the function of the eyespot is to scare away predators, as in the case of eyespots on butterfly wings which mimic owl-eyes.



McCosker suggests this is a case of Batesian mimicry (in which a harmless species gains an advantage by mimicking a noxious species) rather than Mullerian mimicry (in which both model and mimic are noxious). Tests conducted by him did not reveal any toxin in *Calloplesiops*. When a *Calloplesiops* was placed in an aquarium, other fishes appeared startled by the eyespot. Hence, it is likely that the functions of the eyespot are: to startle predators and to complete the resemblance to a noxious and pernicious species.

The eel (top) and the eyespot in its mimic *Calloplesiops* (bottom) that fools predators

one per cent jump in the level of radioactive carbon (^{14}C) for 1909, the year following the Tunguska explosion. Writing in *Nature* (11 August 1977), John Brown of Glasgow University and David Hughes of Sheffield University (UK) suggest that the radiocarbon data could be explained by the searing entry of a comet into the Earth's atmosphere. The passage would produce X-rays, gamma rays and highly accelerated electrons and nuclei which could transform atmospheric nitrogen into ^{14}C (which is taken in by organisms during their lifetime).

It was in the 1930s that Whipple and Astapovich theorised that the explosion had been caused by the explosive disintegration in the atmosphere of the head of a small comet. In 1962, tiny particles of magnetite (an iron ore) and fused rock were found around the site (interplanetary debris is believed to consist of stony material with flecks of iron). In 1966, a Soviet scientist calculated, from the direction and angle at which the Tunguska body hit the Earth, that it had approached from behind the Sun and was never seen because it had been veiled by the Sun's glare.

MUST YOU TAKE A LAXATIVE?

There is no organ of the body of civilised man which is so misused as the digestive tract. It has to assimilate a great variety of food and, in addition, must act as a receptacle for a bewildering variety of drugs. These include drugs (cathartics and laxatives) whose specific function is to help keep the bowels clear.

But cathartics and laxatives in reality do more harm than good. With overuse, they can irritate the bowel lining and affect its muscle tone, so that in course of time stronger stimulation is required to produce any activity. Salt cathartics such as magnesium hydroxide (milk of magnesia) and sodium phosphate also stimulate peristalsis, patients with chronic kidney disease, who may have difficulty excreting magnesium, should be wary of milk of magnesia, and patients on salt-restricted diets should steer clear of sodium-containing laxatives.

Most cases of constipation get cured without the aid of drugs. *The Medicine Show*, a publication of the Consumers' Union (CU), New York, suggests you should normally avoid laxatives containing bowel stimulants like phenolphthalein, senna, bisacodyl and cascara, all of these can produce painful cramping by stimulating peristalsis. If you must use a laxative, CU's medical consultants recommend you restrict yourself to bulk producing laxatives (like psyllium and methyl-cellulose) or stool softeners. The main stool softener in clinical use is dioctyl sodium sulphosuccinate, it works by permitting fluids to penetrate the stool, thus increasing its water content. Some products combine a stool softener with a bulk laxative, or a bowel irritant with an emollient, but CU's medical consultants advise buying a product with only one active ingredient.

WHY HEDGEHOGS ANOINT THEMSELVES

One would imagine that hedgehogs are sufficiently protected by nature. They roll themselves up into a ball when approached by a predator. They may take the offensive and lunge at a predator, erecting the spines on their head — a response known as 'boxing'. The curious behaviour in many species of hedgehogs, called self-anointing, which consists in frothing at the mouth and then spreading the froth with the tongue on to the spines has long been a puzzle. An explanation is now provided by Edmond Brodie, Jr. of the Adelphi University, New York (USA) in *Nature* (18 August 1977). He suggests that the hedgehogs eat toads and smear the toxins in the toadskin on to the spines to heighten the protective value of the latter.

When toads (*Bufo*) were offered to the laboratory-raised hedgehogs (*Atelerix prunei*), the latter first bit the toads and chewed their parotid (salivary) glands, which contain the greatest concentration of skin toxin, and then smeared the resultant mixture of toad skin secretion and saliva over the spines; the toad was then eaten. This self-anointing behaviour is fully developed even in 15-16 day old hedgehogs, that is, before they open their eyes.

Adult hedgehog anointing itself after chewing a toad

To test whether the self-anointing increased the pain inflicted on a predator, the scientist and his colleagues jabbed spines from an *Atelerix* into their forearms, and found that in all cases where spines freshly self-anointed with toadskin secretion were used, there was immediate intense local burning That the self-anointing behaviour is developed before the hedgehog leaves its nest underlines its survival importance.

Besides hedgehogs, self-anointing behaviour has been seen in the tenrec *Echinops*. Tenrecs, in contrast to hedgehogs, wipe the mixture of stimulating secretion and saliva first on to the forepaws before applying it to the spines.

A TREE THAT COMMITS SUICIDE

Most people have heard of the mass suicide committed periodically by lemmings and springboks by drowning themselves in the sea — generally believed to be a natural device to check overpopulation in these species.

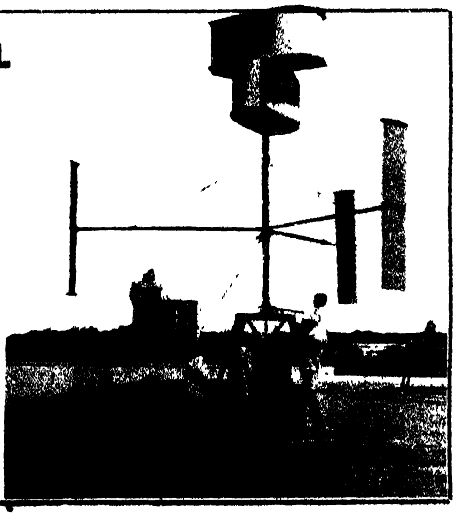
Now comes a report by Robin B. Foster of the University of Chicago's Department of Biology (USA) of a tree (*Tachigalia versicolor*) that dies within a year of flowering. Trees of this species were studied for ten years at the Barro Colorado island in the centre of the Panama Isthmus.

In 1970, at least 18 large trees flowered and all died within one year after release of their wind-dispersed fruits; no vegetative regrowth has been observed from the bases of trees or underground parts. In 1974, 85 trees, of the 430 marked for study, were in full flower on the island and all were dead by May 1975.

Writing in *Nature* (18 August 1977), the scientist suggests that the death of certain individuals is a natural device to increase the survival chances of the progeny. Most tropical canopy trees require a 'light-gap' in the forest canopy for growing. A tree-fall should increase the opportunities for seedlings in the vicinity of the parent. This should hold good for seedlings of *T. versicolor* because, the seeds being wind-dispersed, they are rarely found more than 100 metres away from the parent: they are often found growing in the openings directly created by the fall of an adult.

VERTICAL WINDMILL

The vertical blades of the Darrieus windmill installed at Bangalore by scientists of the National Aeronautical Laboratory respond automatically to wind shifts. The two Savonius buckets at the top are self-starting rotors whose job is to catch enough wind to turn the three-bladed shaft. The turbine reached 70 rpm in 25 kmph winds, generating about one kilowatt of power. Large models may help turn the monsoon winds to good account. One plus point is that the generator, mounted at the base of the shaft, needs no expensive support tower (see also SCIENCE TODAY, November 1975, p. 15).



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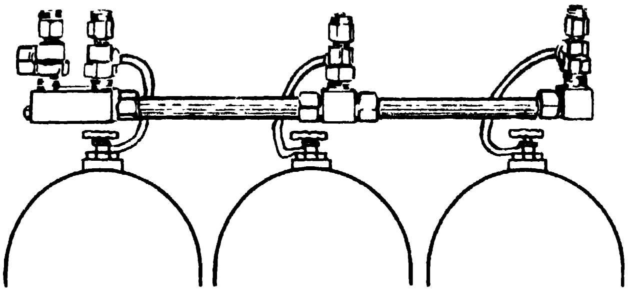

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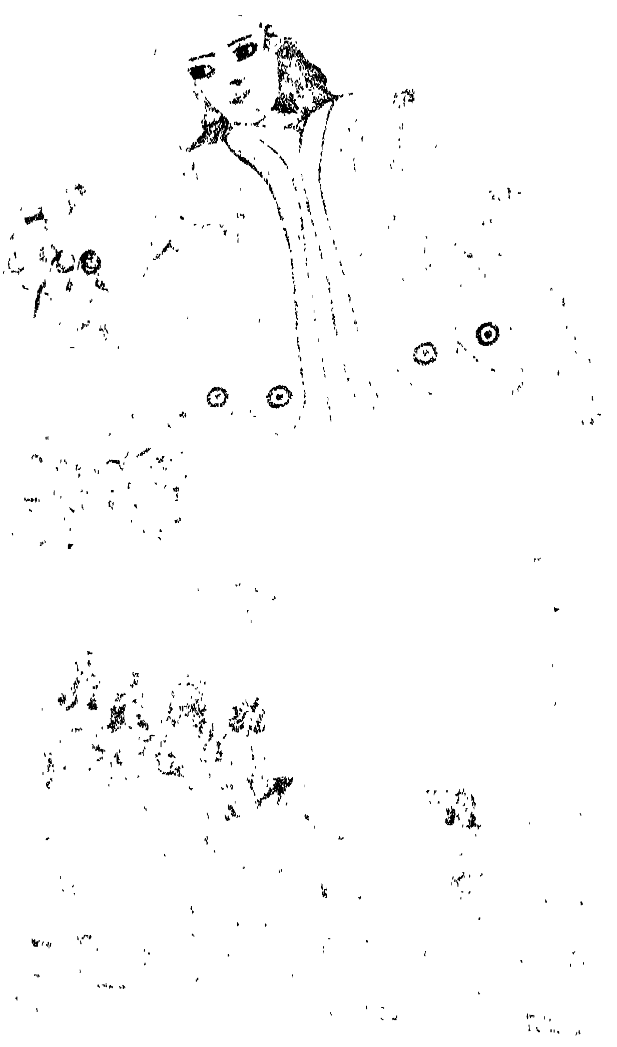


Sushma

OF SHAPES AND SIZES

A. R. P. RAU

To the Lilliputians in Jonathan Swift's story, Gulliver was a giant — scaled up in size several times. But then, if the Lilliputians were of the normal human proportion, Gulliver would have to be very large, very fat and very very heavy — according to the physical laws that govern shapes in nature. How much do we really know why things are the way they are?

All around us, we see a bewildering variety of shapes, structures and forms, both in man-made objects and in the natural world. Only rarely do we pause to ask ourselves why these objects take the particular shapes they do, whether there is any reason behind the forms we see, and whether there are any links between forms which, at first sight, look very different. This is particularly true of forms in the natural world because, at least for man-made objects, we sometimes do see the considerations of utility and design which have led to a particular form. The aim of this article is to set down arguments to support the premise that there is a meaning, in the sense of physics, to the forms we see around us. The forms, whether of animate or inanimate objects, are equally to be understood as quasi-mechanical effects on matter of physical forces.

This is a point of view quite different from that of ancient philosophers to whom form was a metaphysical concept. It is also a point of view that may not be very familiar to many, including natural scientists (and, perhaps, physical scientists as well), since conventional training in biology does not emphasise it. It is, however, a point of view that should be an integral element of the thinking of all of us because such an attitude can be important in understanding how and why these forms arise, and how they change or develop — the study of morphogenesis.

One man of reason who, in the early part of this century, expressed most clearly and strongly this conviction that forms in the natural world are to be understood in terms of physico-chemical forces was Sir D'Arcy Thompson. In his own eloquent words, " cell and tissue, shell and bone, leaf and flower are all so many portions and aspects of matter and it is in obedience to the laws of physics that they have been moved, moulded and conformed ". D'Arcy Thompson's monumental book *On Growth and Form* (Cambridge University Press, 1943), which should be part of everyone's education, is the seminal work in this area and is the precursor of any new developments in the study of forms that may come in the years ahead through advances in mathematics. The present article is essentially a paraphrase of the book. Throughout, many of the examples and illustrations and even direct quotes have been drawn from this book even though, to avoid repetition, this may not always be explicitly stated.

At the very simplest level, simply in terms of the static aspect of forms, so much already falls into place just in terms of the dimensions of the world we live in. That surfaces are proportional to $(\text{length})^2$ whereas volumes are like $(\text{length})^3$ is already enough to make a lot of sense of form. There is, for instance, a small wading bird called the stilt which D'Arcy Thompson uses as an example. It weighs, on an average, 0·11 kg (4 oz) and has legs 20 cm long. If we then look at a bird such as the flamingo, which may weigh about 1·8 kg (4 lb), we can argue that since their weights — and, therefore, correspondingly their volumes — are in the ratio 1 : 16,

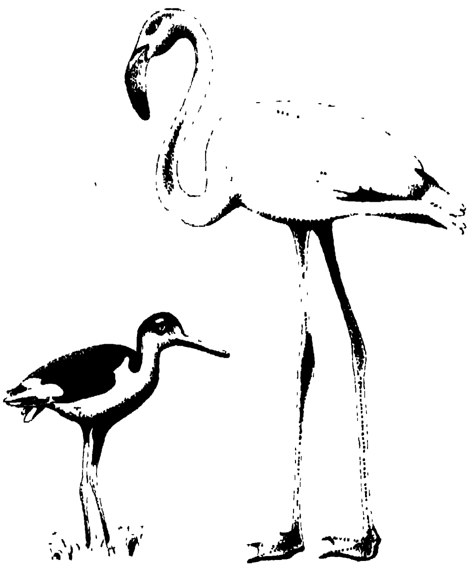


Fig. 1 The stilt (left) and the flamingo (right). The stilt weighs, on an average, 0·11 kg and has legs 20 cm long. The flamingo weighs about 1·8 kg and has legs about 50 cm long. This gives a weight, and, therefore, a volume ratio of 1 : 16 between the two birds, and a leg-length ratio of 1 : 2·5. This conforms to the expected dimensional proportions; volume is proportional to $(\text{length})^3$, or $(2{\cdot}5)^3$ which is roughly equal to 16

corresponding lengths could be expected to be in the ratio $1 : \sqrt[3]{16}$ which is roughly 1 : 2·5, so that the flamingo should have 20 × 2·5 = 50 cm long legs — as it does! Similar birds (in this case, with similar wading habits) have similar proportions and their forms can be correlated. Even in this simplest example, note that we transcend species in establishing a correlation. This is characteristic of many of the conclusions that follow when physical considerations are applied to understanding forms because the concept of species is a biological one and is irrelevant for physical considerations.

As another illustration, one can build a model of a bridge on a table with matchsticks, but if one were to build a real bridge using the same material by merely scaling up the size, the bridge would collapse. This is because the strength of a girder or matchstick varies as the cross-sectional area and, therefore, like L^2. When considering the effect of a force on something like a beam or girder, it is not the total force applied longitudinally, say, at one of the ends, that is important in determining the effect on the beam — the same force on a thick railroad rail does less damage than when it is applied to a thin piano wire. What is relevant is how the force is distributed over the cross-sectional area, the ratio of the force to the area which one calls the stress. A well-known law states that the strain produced is proportional to this stress. Hence, what determines the strength of a girder is, besides the nature of the material, its area of cross-section. But the load, which is a weight, depends on the volume and hence goes like L^3. It follows immediately that there is a relative loss in strength when one scales up the size of a column or girder. So, in building the actual bridge, one would either have to use material of different inherent strength (girders of iron instead of wood pulp) or use a larger portion of girders to other parts of the bridge than in the model.

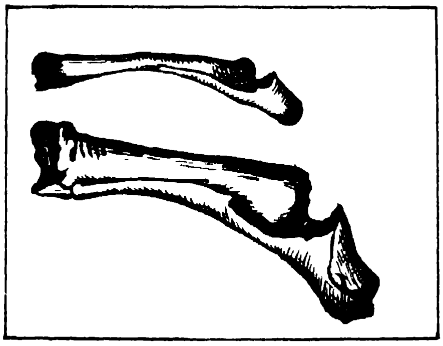
There is an example of the latter solution in nature in the skeletal ratios (proportion of bones to the rest of the body) of land animals. The bones of animals support their structure. Since nature tends to use similar building blocks (this is a general theme that runs throughout this article and represents one of the important basic facts that governs the nature of forms), the breaking strengths of bones, be they bones of a mouse or of an elephant, are almost all the same. There is, as a result, a slight increase in the skeletal ratio in larger land animals, increasing from about 8 per cent in a mouse or a wren through 14 per cent in a dog or a goose to about 17 per cent in man. As a corollary to this necessary increase in skeletal ratios, there is a physical limit to the largest size a land animal can attain. All these elementary conclusions illustrate that quite a bit of form is simply that objects are under competing forces, some of which (like the strength of the skeletal framework) are proportional to L^2 and some (like gravity) to L^3. D'Arcy Thompson sums it up in what could be almost a fundamental theorem in morphogenesis: "*The form of an object is a diagram of the forces acting on it.*" Note that in water the force of gravity is cancelled out by the buoyant force which helps to explain immediately why, unlike in land animals, the skeletal ratio is almost a constant from porpoises all the way up to the largest whales. Also, it further follows that the largest sea animals (whales) may be expected to be, as they indeed are, much larger than the largest land animals (elephants).

Yet another aspect of the surface/volume ratio is illustrated by fruits and vegetables. The strength of the stalk increases as L^2 whereas the pull of gravity goes like L^3. So, in fact, it

Fig. 2A The relative sizes of the front leg bones of two related animals — the bison and the gazelle (smaller). The bison is a larger animal, and its bone is much thicker compared to the length than that of the gazelle bone

Fig. 2B The gazelle bone, with the length enlarged to that of the bison bone (*Physics*, National Council of Educational Research & Training)

2A



2B

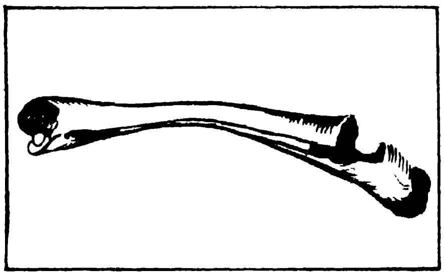
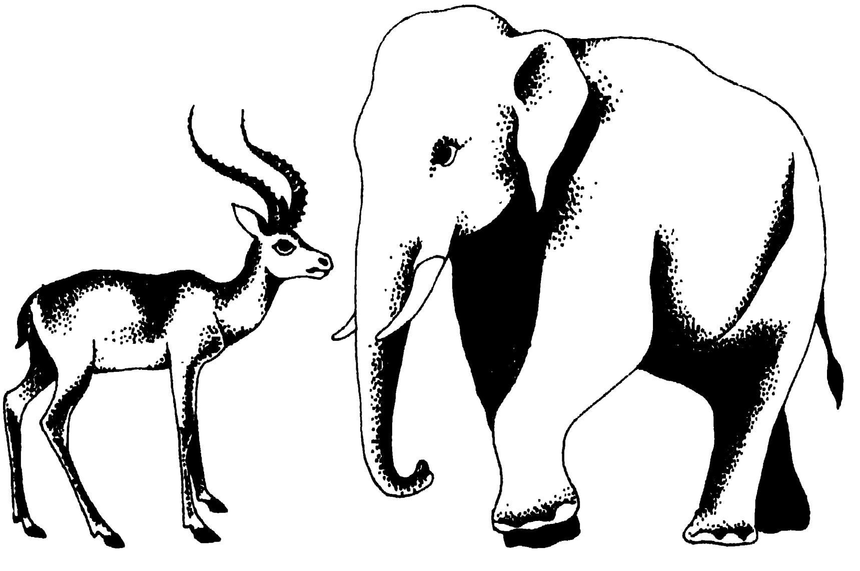


Fig. 3 (below) The gazelle and the elephant. The skeletal ratios increase for larger animals, and a large animal like the elephant has thus grown clumsy and is necessarily less graceful than the gazelle



is not without reason that " tall trees do not bear large fruits on slender branches and melons and pumpkins must lie upon the ground "!

Science fiction stories of powerful, large ants making enormous tunnels at fantastic speeds are just that — fiction. What they have discounted in merely scaling up capabilities along with the size is the feature that an increase in size has a necessary effect on other characteristics and capabilities of the form so that such ants would be necessarily more sluggish than the familiar little ones that we know. That the skeletal structure increases and becomes more complicated for larger animals, that larger animals like elephants and hippos have grown clumsy at the same time as growing big and are necessarily less graceful than gazelles are all aspects of the surface/volume story. As J. B. S. Haldane puts it in a very readable little essay, " On being the right size " (*Possible Worlds*, Harper Brothers, New York, 1928), " The higher animals are not larger than the lower because they are more complicated; they are more complicated because they are bigger ". Were the pull of gravity to be increased appreciably (suppose, for instance, we were considering, hypothetical beings on a large planet like Saturn or Jupiter), the majority of land animals would be short-legged or serpents. The inexorable effect of the pull of gravity is to be seen everywhere. A vertical column (say, a cylindrical one), for instance, bends under its own weight and one can show (see T. A. McMahon, " The Mechanical Design of Trees ", *Scientific American*, July 1975) that an increase in height must, for stability, be accompanied by an increase in diameter according to the relation: diameter is proportional to $(\text{height})^{3/2}$. This immediately accounts for the slender look of young trees compared to the squatter appearance of older ones. It also sets a limit to the maximum height a tree can attain (or, for that matter, why a cat's tail cannot stand straight even though a kitten's can!) when one takes into account the average density and elastic modulus of wood and the feature that the diameter is usually some reasonably small fraction of the height. Remarkably, the tallest trees in nature do, in fact, approach roughly the value one gets for such a limit set by physical considerations. This is an example of what might be a basic tenet in the study of biological forms, namely, that " the physics " sets natural limits on the variability of a certain form and that nature fully exploits this niche through biology, filling (almost) the entire niche and giving us many examples of forms close to the physical limits. The above statement also serves as a caution on how to view many of the examples and illustrations in this article. They are not to be considered as rigid theorems precisely defining the forms we see but more as guidelines around which there could be, and often is, a fair variability, though not, as a physicist would say, by orders of magnitude. Also, it is the extremes within the biological variability, such as the largest or tallest or smallest that exhibit most clearly the conclusions one arrives at on the basis of physical considerations.

To conclude this section on the static aspects, it should be kept in mind that the nature of the competing forces that determine the form of an object can vary from environment to environment. We have already seen that gravity may play little role for sea animals, unlike the dominant role it has for land animals. At another level, the very small, as in the case of tiny insects or mosquito larvae or at the even smaller level of bacteria and cells, gravity may again take a side role compared to other forces such as surface tension or viscosity. A man immediately after a bath is only a fraction of a per cent heavier than usual because of the water sticking to him, whereas a fly is twice as heavy when wet and quite helpless. This is again because the surface/volume ratio is larger, the smaller the object. In the structure of such small organisms, where surface forces like surface tension play a dominant role, one generally sees circular or spherical shapes (cells, bubbles, drops, etc), relatively less complicated shapes than at our level. Incidentally, it is interesting that again at the very largest level, such as that of planets and stars, where gravity really is all-important and dominates all specific solid state forces in matter, one again sees spherical shapes. That this happens only for very large objects is clearly illustrated by recent photographs taken by satellite missions to Mars of the two moons of Mars, Phobos and Deimos, which are only a few ten kilometres across and which show up on the pictures as very irregular objects far removed from spherical symmetry.

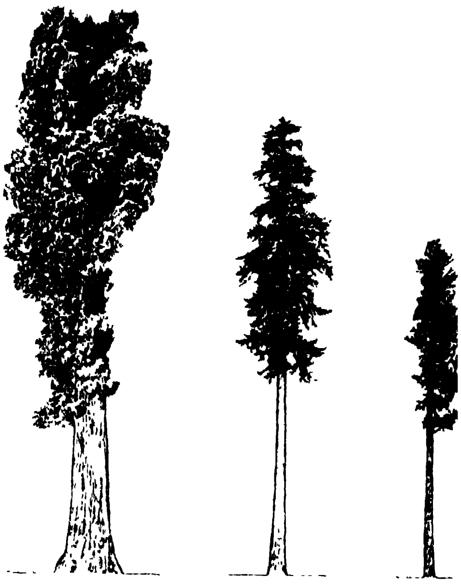
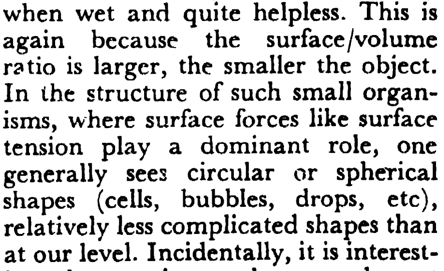


Fig. 4 Taller trees are proportionally thicker than shorter ones. Three large trees, a giant sequoia (left), a Douglas fir (centre) and a ponderosa pine (right), show the diameter of a tree trunk at its base increases as the height increases. The mathematical model of elastic similarity requires that the base diameter of a tree increases as the 3/2 power of the tree height. The base diameter of the sequoia tree, which has been damaged at the top, suggests that it would have grown to 91 metres (dotted line) if undamaged (*Scientific American*, July 1975)

Fig. 5 Galileo wrote that a bone of a greater length must be increased in thickness in greater proportion to retain a comparable strength. This drawing by Galileo shows his concept of scaling. The large bone is about three times longer and nine times thicker. This actually is wrong; the large bone should be only about 5·2 times thick



Dynamics

Besides the static aspects of forms discussed above, the surface/volume ratio plays a crucial role in dynamics as well. The larger the animal, the faster it can walk, and larger fishes swim faster than smaller ones. Consider walking, for instance. There is obviously an economy of effort if the legs swing at the rate of a natural period of oscillation — the pendulum rate. This rate, which varies inversely as the square root of the length of the leg, will remain the same regardless of how fast one walks. To walk quicker, we step out, increasing the stride or the amplitude of the swing but not the rate itself. The rate is only increased when we begin to run, at which time we crouch, thus reducing the pendulum length! So, in walking, the length of the stride, like any other linear dimension, is proportional to L whereas the time period of the swing goes like $\sqrt{L}$. As a result, the speed is proportional to $\sqrt{L}$. This is called Froude's Law and is well illustrated by the fact that man can walk at about 8 kmph whereas a fly can walk some centimetres a second as one would expect from the roughly 1 : 200 ratio of their heights. Though the detailed considerations with regard to swimming are somewhat different, the same sort of dimensional result applies here as well — that the speed of a fish is roughly proportional to $\sqrt{L}$. Also to flying. The larger the bird or the aeroplane, the faster it has to fly to just stay aloft. Only a hummingbird, not a hawk, can hover! Care must be taken, however, to keep in mind that such a Froude's Law is not always applicable and is only true for what one calls streamlined flow. There are certain regimes of size and speed where the flow is drastically different and such a square-root law inapplicable. This is an aspect of a general caution in all such arguments based on physical considerations — one should be very clear on their regions of applicability.

As another interesting illustration, consider the jumping capabilities of different animals. One is often impressed by the feature that a flea can jump 200 times its own size whereas we can only jump roughly our own heights (the Olympic record is a little over 2 metres). In looking at this more closely, we see that the impulse generated by the muscles when we jump, increases as L^3 (the cross-section of a muscle multiplied by the contraction through a certain distance). The velocity of take-off, therefore, which is the impulse divided by the mass, is roughly constant, since the mass also goes like L^3. Since one knows that for a given vertical take-off velocity, all objects, regardless of their mass, reach the same height, it follows that the maximum height for the jump is the same for all animals be it a flea or a horse or a man — a few feet. Seen in relation to the body size it is, of course, much more impressive in the case of the flea than for a horse or a man.

Energy consumption

The surface/volume ratio and its character of being larger for smaller objects also affects energy considerations and the metabolic activity of animals. This follows naturally because loss of heat takes place from the surface whereas the total energy required or generated depends on the volume of the animal. Everyone is familiar with puppies huddling together for warmth. The loss of heat is more crucial the smaller the animal and, as a result, insects tend to have hard or scaly skin to cut down on evaporation losses. They also consume large quantities of food relative to their weight and, as a corollary, eat almost all the time! For mammals, where heat losses are particularly crucial, since a relatively constant temperature is to be maintained, there is as a consequence a minimum size. A mammal cannot be the size of a tiny insect. This conclusion is further sharpened when one looks at extreme environments like the Arctic regions or the oceans. The smallest mammals to be found there are much larger than the smallest ones in tropical lands. That heat considerations are more critical the smaller the animal means that the relative amount of food consumed increases. A mouse eats its own weight of food every day whereas we can get by with a fraction of ours. Not only the amount consumed but the rates involved, such as the heart beat and the respiratory rate and the metabolic activity in general are speeded up. As a consequence, the smaller the animal, the faster it dies off, or it has a shorter life span. Such a direct correlation between metabolic activity and life span with the size of the animal is exhibited by any chart giving such comparative figures all the way from the mouse to the elephant and the whale.

Sound and vision

Small animals, in general, make squeakier cries than larger ones. Just on dimensional considerations alone this is to be expected because the wavelength of the sound generated, like any length, should be smaller for the smaller animal, thereby making the frequency higher. Part of the range of sounds generated may even lie outside our range of hearing — a hummingbird, for all we know, may be humming all day long. Incidentally, that the frequency ranges are different means that all the time scales are different and a second may mean far more to an insect than to us because " far more things happen to it in a second than to us." This sort of counterbalances our earlier conclusion regarding shorter lives for the smaller animals — true, but then, they lead fuller lives!

Vision is another story because of an externally imposed aspect, namely, that the Sun puts out a major portion of its energy in a certain band of wavelengths roughly around what we call the visible region. Hence, all animals have developed a visual acuity for this region. Further, in all of them, the rods and cones in the eye cannot vary very much in size because of optical limitations due to interference and diffraction. Here is an actual physical explanation in one instance of why nature uses similar building blocks. One can go further because, given the constancy in size of the rods and cones, the eye itself in all animals can never be very small nor very big. This is because only a small portion of the retina is ever used in an observation and there is not much to be gained in terms of the field of view by having a large eye

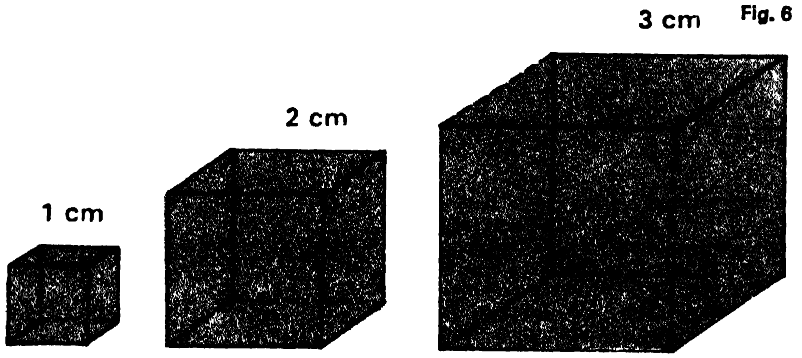


Fig. 6

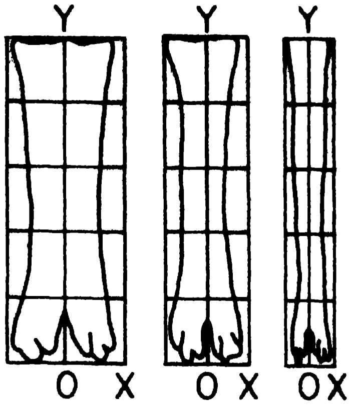
A surface area is defined by two independent (mutually perpendicular) lengths and we say it has the dimensions of L^2. Any area is always measured in units like yd^2 or km^2. Similarly, a volume is defined by three independent lengths and has the dimensions of L^3. When an object in our three-dimensional world is scaled up or down in size, preserving the shape, it is simple from dimensional considerations alone, therefore, to see what happens to surface areas and volumes. For concreteness, consider a cube of side 1 cm. If all lengths are scaled up by a factor c, a bigger cube results, with the total surface area of the six faces going up from 6 cm^2 to a number c^2 times as large and with the volume increasing from 1 cm^3 to c^3 cm^3. The above example illustrates a general consideration: when length is scaled by a factor of c, keeping shape constant, surface area gets scaled by c^2 and volume by c^3. A.R.P.R.

in a large animal. The biologically remarkable fact that nature has, in the course of evolution, evolved in different lines of species essentially the same kind of eye finds its explanation, therefore, along the lines of such physical arguments. Only in insects is there a slight difference. Since diffraction effects would be disastrous were they to have a single eye similar to ours which would mean a very tiny pupil, insects have compound eyes and an " aperture synthesis " of the images of all of these is an integral part of their visual system.

Function determines the form

Everyone would accept the principle that the structure of many man-made objects is guided by the functions they are supposed to perform. As a simple example, coastal cities whose importance depends on handling sea-going ships will have long narrow wharfs and jetties jutting into the water so that many ships can be handled in the harbour. The characteristic appearance, therefore, of such cities is a simple example of the geometrical fact that such a construction is the way to achieve a large perimeter for a given plane area. Similar considerations on the three-dimensional level guide nature in its design of biological forms so that much of form can be understood in terms of the functions it has to perform. Organs such as the lung and intestines which have to absorb nourishment from the outside and are thus surface-dominated in their functions take characteristic shapes involving folds, doubling-ups, complex networks and convolutions, all of which tend to increase the amount of surface for a given volume. There is roughly $1 m^2$ of lung surface per kilogram of the body weight of an adult human, so that the total lung surface is the size of a tennis court! Incidentally, the inevitable constraint imposed on accommodating these large surface areas in a reasonably confined volume has repercussions on the overall appearance of the object. A small worm, which does not require that large an intestinal structure, can be reasonably straight and long but a larger animal, if it were to be linear, would have to be of an impossible length. Instead, we do not see linear shapes when we get to larger animals but rather more " filled-out " three-dimensional structures.

At the cellular level too, it is possible, and even very likely, that the same feature of the function determining the form is operative. This may lie behind the remarkable fact that biological cells are all roughly the same size. It is indeed striking that, even though in the finished forms the elephant dwarfs by several orders of magnitude the mouse or the ant, in terms of the basic cells that constitute these various forms, and all biological cells in general, there is never more than a factor of ten difference in size. This is yet another instance of nature using similar building blocks and it is very plausible that it results from the competition between the consumption of energy (which is proportional to volume) and its capture (through the surface), the difference between these being the energy available for synthesis and, thereby, the growth of the cell.



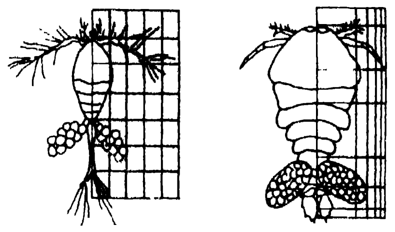


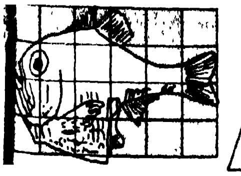
Fig 7 (top) The cannon bones of an ox (left), a sheep (centre) and a giraffe (right) are related to each other by the scaling of the horizontal axis

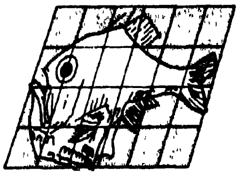
Fig. 8 (above) Relation between the sizes of two copepods of different genera

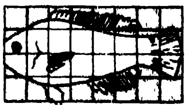
Transformations

A striking aspect of forms in nature is the relationships, sometimes very simple geometrical ones, that are often to be seen between different finished forms as a whole or between parts of these forms. *On Growth and Form* contains several examples of this, as shown in the representative sample of figures given on this page that have been taken from that book. One (Fig. 7) compares the cannon bones of an ox, a sheep and a giraffe, showing that they are simply related to each other by an overall scaling of the horizontal axis. Even more striking is the one (Fig. 8) which shows the simple geometrical transformation of the axes that takes two copepods of different genera into each other, though at first sight (without the background grid, for instance) they look very different; Fig. 9 is a similar illustration of fishes of related families and, with somewhat more complicated transformations, of two sun fishes which are of different families according to their biological classification. D'Arcy Thompson also provides examples of skulls of various ungulates showing a continuous topological thread from the skulls of extinct rhinos through those of present-day rhinos to those of tapirs and horses and, most remarkably, even of rabbits which, as he says, is a clear demonstration of the close affinity of the rodents and the ungulates. Fig. 11 is another example with skulls of various apes and the link to that of man. One can in this way make this transformation study even a predictive one by thinking of a continuous topological distortion that carries one from one of these skulls to the others and looking for intermediate configurations in such a distortion, " missing links ", of which we may not have direct evidence. Another step would be to speculate on what physical parameters and changes of environmental pressures could have made the course of evolution trace such a path. The

Fig. 9 Topological illustrations of fishes of related families


ARGYROPELECUS OLFERSI


STERNOPTYX DIAPHANA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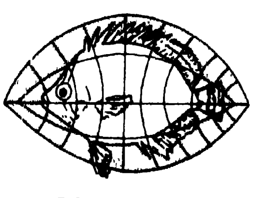
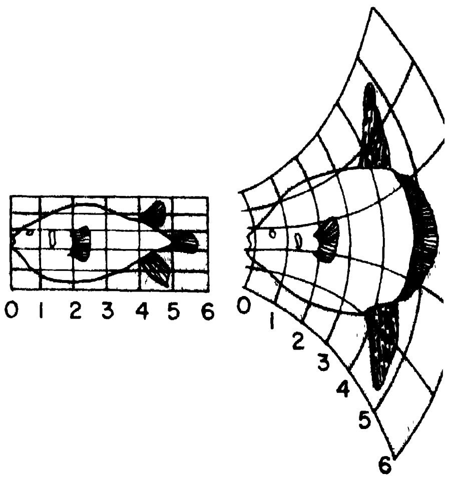

POMACANTHUS



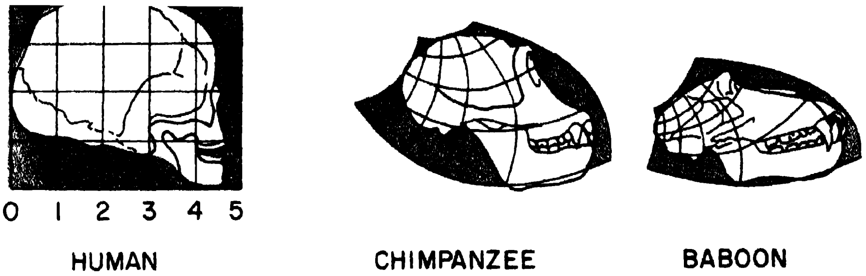


Fig. 11 A human skull and that of the chimpanzee and the baboon

presence of such simple transformational links is an illustration of Newton's words, " Nature delights in transformations ", and clearly indicates the role of topology in understanding biological forms. Yet another aspect of such transformations, applicable now not to comparing different forms, but to the various stages of growth of any specific form is best stated in D'Arcy Thompson's following words on " Nature and the glass-blower ".

" It is clear that we may account for many biological processes of development by the existence of lines of constraint which limit and channel the expansive forces of growth. There is a close parallel to the actions of a glass-blower who starts his operations with a tube which he closes at one end so as to form a whole vesicle within which his blast of air exerts a uniform pressure on all sides. The spherical conformation this would produce is modified by the resistances set up as he lets one part or the other be unequally cooled or heated. Nature also starts with a simple tube — the alimentary canal, the arterial system, the central nervous system of vertebrates. And with them nature does just what the glass-blower does and we may say no more than he. She expands the tube here, narrows it there, thickens its walls or thins them, blows off a lateral shoot, bends the tube, infolds the walls, etc. The gravitational field is part of the complex fields of force which influence and determine the forms of the organism ".

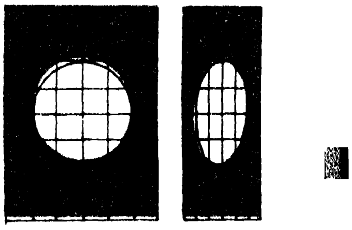


Fig. 10

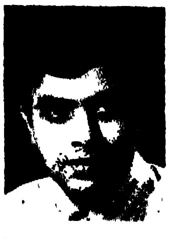
Topological deformations

A figure drawn against the background of a co-ordinate grid can be distorted into a topologically equivalent figure by simple rules for distorting the grid. As a simple example, a grid can be distorted in one direction by compressing the distances in that direction. Any object drawn against that grid will take on a more elongated appearance — the circle shown becomes an ellipse. Co-ordinate axes of a system can be changed, while keeping fixed the points being described, by a mathematical formula. For example, stretching the x-axis by a factor of two results in the co-ordinate transformation $x' = \frac{1}{2}x$, $y' = y$. More complicated transformations like rotating the axes, or stretching them by different amounts, or a combination of a rotation and a stretch will result in more complicated transformations [illegible]

It would be interesting to carry out experiments on the growth of biological organisms in a weightless condition or in conditions of artificial gravity. This may shed considerable light on the nature of the influence of external forces during the process of growth. Sometimes gravity may not be all. Gravity, surface tension and viscosity all play a role when one liquid sinks into another. These forces will be relevant, therefore, for cellular and bacterial growth. As another example, the shape of a drop of ink as it sinks into a container of water is dramatically reminiscent of the shape of a jellyfish and clearly there are evolutionary implications here.

Conclusion

The last section, the last few lines of it in particular, form a natural lead-in into what may lie ahead through new developments in mathematics, in particular in a branch of topology which is being called catastrophe theory. The evidence presented in the various sections of this article, which is only a small sample of the total evidence available, makes it quite clear that much of the form of the natural world and the objects in it is to be understood as a consequence of the physical forces that have shaped these forms. The last section shows the important role topological transformations play in growth and form, so that the subject of topology has clearly a crucial role in theoretical biology. What was missing till recently is a precise way in which this programme of using topology is to be implemented, the mathematical language that is necessary to carry out this programme. The recent developments in catastrophe theory (see Rene Thom, *On Structural Stability and Morphogenesis*, Benjamin, Inc, 1975, also V. Monteiro, *Catastrophe Theory*, SCIENCE TODAY, September 1975, p. 13) may provide the answer and the theorems and the mathematical language and concepts for handling these topological transformations. One essential aspect of these transformations is that they are often sudden and " catastrophic " — hence, the name given to the theory. Another aspect is that often only a few independent variables govern the catastrophic transformation of an entire system. These features are illustrated by the suddenness of the change in biological transformations — the environment may be changing gradually but, suddenly (in terms of natural biological or evolutionary time scales), a whole species may be transformed. This is, of course, the " catastrophe ", and may account for why so few transients are seen. It also is clearly relevant for those who search for missing links in evolution and is surely responsible for why such a search is so arduous because these transients are rapidly traversed by the course of evolution, leaving behind few traces or none. The usual mathematics that is familiar in the physical sciences, and which has been used increasingly in theoretical biology, is the one of differential equations where small changes in initial data lead to small effects. Such mathematics is quite inadequate to handle the situations we have been describing where small changes have large, catastrophic responses. The new mathematics of catastrophe theory remedies the shortcoming and it is for this reason that there is considerable excitement now about the prospects for major breakthroughs in the field. In the years ahead, we may expect to see catastrophe theory play this role as a more mathematically rigorous treatment of D'Arcy Thompson's considerations with far-reaching implications for our study of forms in the world around us — why things are the way they are.



Dr. Rao (32), who obtained his M Sc from Delhi University and Ph D from the University of Chicago, USA, is currently an Assistant Professor of Physics at the Louisiana State University, Baton Rouge, USA. Earlier, he had done research in theoretical atomic physics at the New York University and the Tata Institute of Fundamental Research, Bombay. His other interests are mathematical and astro physics.

ZOOLOGY

How Desert Scorpions Hunt at Night

It appears that the science of seismology and electrophysiology are combined by the desert scorpion (*Paruroctonus mesaensis*) in hunting its prey at night. This is the conclusion of some experiments conducted by Philip H. Brownell at present at the Department of Physiology, Medical School, University of California, San Francisco, and reported in *Science* (**197,** 479, 29 July 1977).

The sand scorpion is a very good hunter and can locate its prey up to 50 cm away in total darkness. Its main food is the burrowing cockroach (*Arenivaga investigata*) which, however, buries itself as soon as it can detect the scorpion's approach. When it is out hunting, the scorpion adopts a characteristic pose with its legs spread out in a circle about five centimetres across. Its range, accuracy and speed of localisation of the prey are such that in three or four orientation movements, lasting about one second each, the scorpion can position itself over its prey. Thereafter, movements of the cockroach provoke a fast digging behaviour from the scorpion that uncovers the prey. Dr. Brownell found that scorpions could locate their prey only when it was in contact with the sand. He, therefore, conjectured that some signal must pass through the sand to indicate the position of the prey relative to the scorpion. He has, in fact, investigated the nature of the signals.

He buried piezo-electric transducers in the sand to see whether small movements of the cockroaches can be transmitted through the sand for any distance. He found that sand can conduct two sorts of waves, comparable on a small scale, to seismic waves. There was a fast compressional (P or pressure) wave that spread out spherically from the disturbance and a slower Rayleigh wave travelling out in a circle on the sand surface.

Having discovered this, he turned to the scorpion to determine whether it is capable of detecting these waves. He found that at the tip of each of the eight walking legs are two types of movement—sensitive receptors, the tarsal hairs that support the leg on the sand and a group of eight slit sensilla (the basitarsal compound slit sensillum) in the cuticle of the last joint in the leg. He managed to insert microelectrodes into both types of sensor and to record their response to a simulated cockroach at various distances. The records showed that the fast wave was detected first by the hairs and then the slow wave was detected by the slit sensillum.

He found that at five centimetres both the hairs and slit receptors actively responded, but as the distance increased the tarsal hairs began to fail. At 10 cm, the hairs did not always respond and at 20 cm only the slit sensillum responded, leading to the conclusion that the surface waves are used to locate the prey at long distances. This was confirmed by making a small hole (250 micrometers) in the cuticle of the slit organ. This altered the scorpion's accuracy, whereas removing the tarsal hairs had no effect. Dr. Brownell concludes that it must be the slower, surface waves detected by the receptors that convey the necessary information. The Rayleigh waves travel at about 40 m per second in loose sand and the scorpion picks up these waves and measures the delay of about 1 microsecond between the widely spaced first and last legs to detect the direction of the prey.

Sand-dwelling scorpion exhumes the burrowing cockroach it has located by sensing compressional and surface waves generated by the prey's movements

CELL BIOLOGY

Programming Genes

Genes that become inactive during cell differentiation can be reactivated, in the absence of cell division, by normal components of oocyte cytoplasm. This is the main conclusion of a research work undertaken by Dr. J. B. Gurdon of the Medical Research Council Laboratory of Molecular Biology, Cambridge, England, who has specialised in research on gene control in eukaryotic cells. In collaboration with Dr. E. M. De Robertis, he has shown in a recent issue of the *Proceedings of the US National Academy of Sciences* (**74,** 2470, June 1977) how genes can be reprogrammed. In fact, they have found that the inactive genes of a mature frog kidney cell can be reprogrammed to become active and behave like egg cell genes if they are transplanted into an immature egg cell.

All cells, being the direct descendants of one egg cell, contain genes that enable them to become any kind of body cell. Most of the genes are normally switched off, and only some are expressed at any stage in a cell's lifetime. One of the principal characteristics of animal development is that genes that become inactive in the course of somatic cell differentiation rarely become active again. An experimental reversal of this stable inactivation would make it possible to investigate the molecular basis of gene control in development.

They transplanted the nuclei of the kidney cells of the frog *Xenopus laevis* into oocytes of the newt *Pleurodeles waltlii* from which the nucleus had been removed. The result was that the oocyte produced frog oocyte proteins and not the proteins characteristic of a kidney cell. The proteins were analysed by two-dimensional gel electrophoresis. They believe, for several reasons, that the activation of frog oocyte specific genes resulted from the translation of mRNAs synthesised by the injected nuclei within the newt oocyte. According to the British biologists the gene expression by *Xenopus* somatic nuclei has been " reprogrammed " by the *Pleurodeles*

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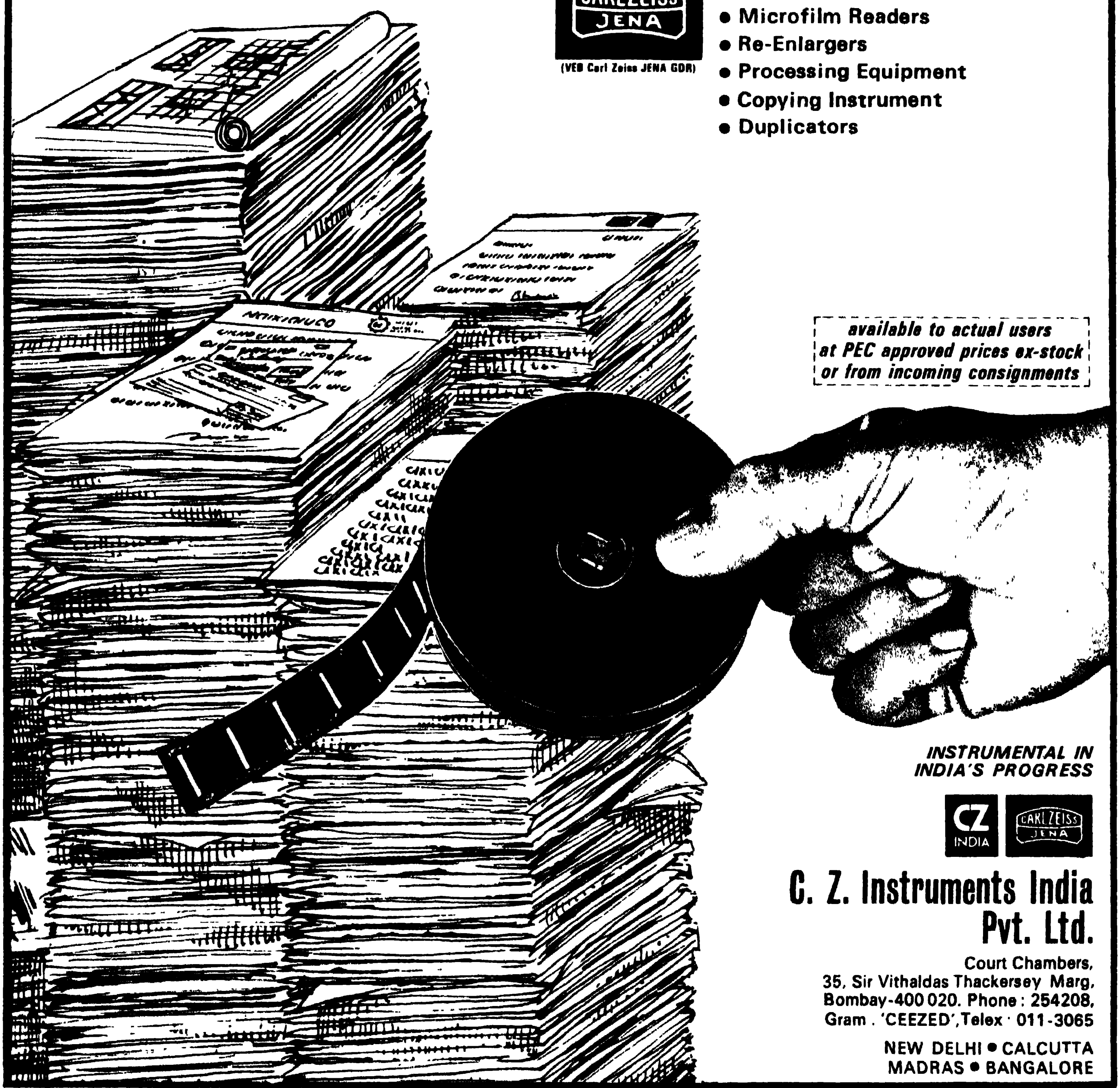

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oocyte cytoplasm, since the proteins produced were frog proteins and not newt proteins. Of great interest is the fact that the expressed genes include some of those which were previously inactive in the somatic cells. An important implication of the results is that the oocyte cytoplasm contains special molecules which switch on the required genes.

PARTICLE PHYSICS

Discovery of a Fifth Quark ?

Exciting discoveries are being made in the field of particle physics in the last few years. The latest one, from the Fermi National Accelerator Laboratory in Batavia, Illinois, USA, (if confirmed) may be the discovery of a single particle of energy 9·5 billion electron volts, the highest mass particle discovered so far. The speculation is that this particle may be made up of the fifth quark that some theoretical physicists have conjectured.

The search for dileptons or pairs of leptons (electrons or muons) in the products of various kinds of collisions between particles and particles and particles and targets has become the pastime of many particle physics groups in recent years. The sixteen physicists from the Columbia University, New York, Fermi Lab and the State University of New York at Stony Brook, New York, have in their experiments, reported in the *Physical Review Letters* (**39,** 252, 1 August 1977), bombarded copper and platinum targets with protons of 400 BeV from the Fermi Lab's synchrotron. They observed a strong enhancement at 9·5 BeV in the mass spectrum of 9,000 dimuon events with a mass $m_{\mu^+\mu^-}$ greater than 5 BeV. The muons produced were analysed in a double arm magnetic spectrometer system consisting of proportional wire chambers, scintillation counters and gas-filled Cerenkov counters.

The experimenters had not given any interpretation of the results in the published paper. However, the possibility that they had discovered a short-lived particle of mass more than ten times that of the proton which decays into a pair or pairs of muons cannot be ruled out. The large mass also suggests the possibility of a bound state of two or more particles, a baryon molecule or a charmonium molecule. While several interpretations of the event are expected shortly, the original experimenters have at a meeting of the European Physical Society at Budapest urged that they may have discovered evidence for the existence of a fifth quark.

Quarks, theory postulates, are subparticles from which most of the known subatomic particles are built up. Three years ago, three quarks, called " up, down and strange " (and three corresponding anti-quarks) were enough to explain the properties of all the subatomic particles then known. But the discovery of the psi particles in November 1974 (see SCIENCE TODAY, January 1975, p. 8) changed the picture. Theorists now suggest the existence of at least six quarks to explain the exotic behaviour of the newly discovered particles. The existence of the fourth quark, " charmed quark ", was confirmed last year (see SCIENCE TODAY, September 1976, p. 24). Once the charmed quark was in the picture, symmetry principles and other considerations led to the opening for a fifth and sixth quark, the " top " and " bottom ", and rather whimsically designated the " truth " and " beauty ". Though the evidence for the fifth quark is at best secondary, the group led by L. M. Lederman of Columbia University feels that its data fit in well with the interpretation that the enhancement it had observed is a particle made of a " bottom " (beauty) quark and a " bottom " anti-quark. They have designated the assumed particle upsilon.

ASTROPHYSICS

More Light on X-ray Pulsars

X-ray astronomy, more than a decade old, has established itself, in its own right, as a separate branch of modern astronomy. But, there are still many peculiar phenomena for which explanations are being continuously sought. One of these is X-ray pulsars, emission of X-radiation in periodic pulses. The first object in this category was discovered about six years ago.

Hercules X-1 has proved to be one of the most enigmatic of more than a dozen pulsing X-ray stars so far discovered. It emits a pulse of X-rays every 1·24 seconds, but the pulse period itself varies in a sinusoidal manner every 1·7 days. What is more, it stops emitting radiation altogether for nine hours in every 1·7 day period. The consensus among astronomers is that Hercules X-1 is a neutron star and that it has a very strong magnetic field of the order of a 1,000,000,000,000 (trillion) gauss. Its companion is HZ Herculis, a star already well known for variable optical brightness. The matter in the outer layers of HZ Herculis are stripped off and accreted by the neutron star.

The mechanism of emission of X-rays is suspected to be synchrotron radiation, the type of radiation emitted by charged particles accelerating in a strong magnetic field. The highly ionised material from HZ Herculis is accelerated in the magnetic field of the neutron star, Hercules X-1, as it travels towards the magnetic poles, releasing much of its energy in the form of X-rays. If the magnetic axis and the axis of rotation do not coincide, then the X-radiation will be pulsed with the star's rotation period of 1·24 seconds. Possibly, Hercules X-1 spends nine hours of its 1·7 day period behind HZ Herculis and is thus hidden from the Earth's view.

Some support to the idea that the X-rays may arise from streams of ions from the normal star accelerating in the collapsed star's strong magnetic field has now been provided by a team of astronomers from the Blackett Laboratory, Imperial College, London in a letter to *Nature* (**268,** 508, 11 August 1977).

The team consisting of M. J. Coe, A. R. Engel, J. J. Quenby and C. S. Dyer had a scintillation telescope covering the energy range 26 keV to 1·2 MeV on board the United Kingdom satellite, Ariel 5. They observed a significant X-ray flux excess in the 56-94 keV band with a characteristic line feature at 64 keV. On the assumption that the line is due to synchrotron radiation from the poles of a neutron star, they obtain a value for the magnetic field of the star of the order of 7,000,000,000,000 gauss, both on the classical theory and relativistic quantum mechanical treatment. This value is in agreement with theoretical assumptions suggesting that synchrotron radiation indeed may produce the X-rays. The Imperial College team concludes that if its explanation of the observations is correct, a new way of exploring pulsar magnetic fields has opened up.

K. A. NEELAKANTAN

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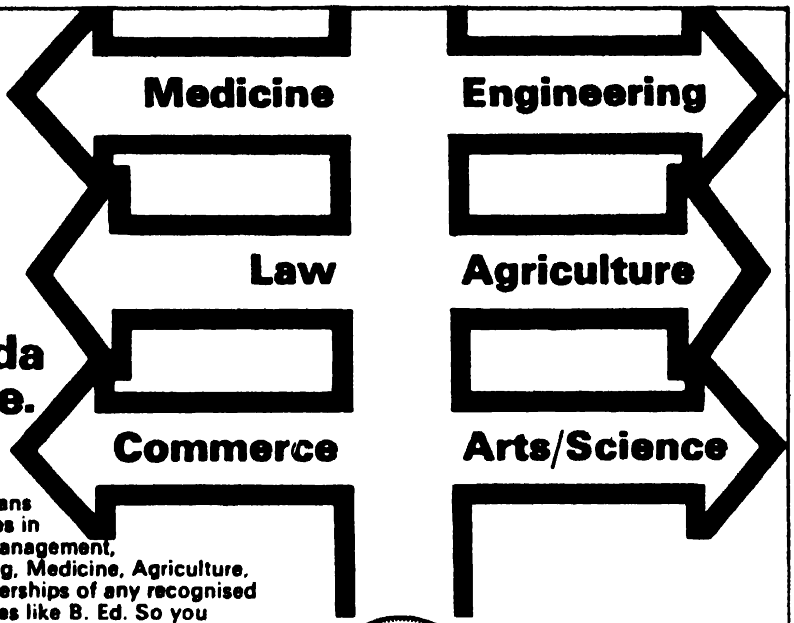

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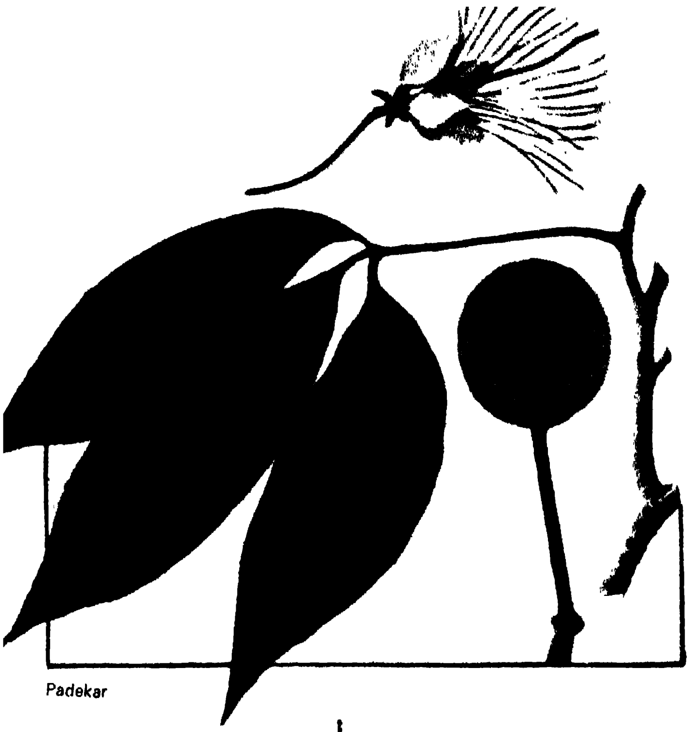


Barna leaves, flower and fruit

Padekar

let's get to know our trees!

7 MORE DECIDUOUS FOREST TREES

During this time of the year, the monsoon shows signs of receding from a large part of the Indian peninsula, after having contributed to the growth and regeneration of innumerable plant species all over the land. This is the time when the richness of the woodlands is at its peak, for the luxuriant plant growth, especially of the titans of the forest, the trees, has benefited the largest number of small life around. The grubs of insects have fed and fattened on the foliage, as did other creeping and crawling creatures; reptiles and birds have found shelter, safety and food in the leafy bowers; animals, too, are assured of a rich fodder for perhaps a few months to come before the massive leaf-fall which commences in winter and continues into early summer.

An impressive deciduous tree familiar to many of us as an ornamental garden or roadside tree is the **queen's flower** or **jarul** in Hindi (*Lagerstroemia speciosa*). The jarul is a denizen of the forests of south India as well as eastern India spreading eastwards through Burma into China and Malaysia. In forest regions where the soil is damp, as in the vicinity of streams, the tree reaches good proportions and rises to over 20 metres in height, whereas many specimens in cities are smaller in size.

The jarul is at its most beautiful between April and July when its flowers, which are borne on the end branches in panicles, thrust outwards. Though a deciduous tree, it is never really completely leafless since the leaf-shedding of the cold season and early summer is quickly replaced by new leaves; the old leaves turn yellow and then red just before they fall off, and this, too, adds a touch of colour to the tree. Each smooth and shining leaf is about the size of one's outstretched hand and many leaves arise from thick stalks which reach out and droop slightly. Its mauve and pink flowers, massed together in clusters around a stout stalk, are the most impressive and delightful. Many flowering branches push upwards at the same time in majestic floral explosions. The flowers at the base of an inflorescence turn a paler shade as they grow older and one can observe a transition of colours along the branch — the younger flowers higher up in bright hues varying from mauve to purple and pink, and those at the top in green buds waiting to open.

The jarul flower is about 5 cm in diameter and is symmetrical; the green calyx is broadly tubular, almost cup-like with five or six pointed projections which persist even after the fruit develops; the petals, six in number, arise from a small disc from slender, narrow bases (called claws) and spread out radially; each petal is rounded at the apex, wavy and crinkled like crepe paper. The true beauty of the flowers comes out best when they are back-lighted by the Sun low in the sky — the soothing pastel hues then stand out, imposing yet not aggressive.

Jarul fruits are round capsules with six compartments in each. These remain on the tree for a very long time, and it is usual to see old fruits of the previous year still clinging to the branches. Each capsule splits open longitudinally into its six constituent loculi discharging many small, thin seeds, each of which is winged at the apex.

The jarul is an important timber tree, second in importance only to teak; the reddish, walnut-coloured wood, being hard, strong and elastic, is used for making boats, carts, planking and the like. The smooth, pale-coloured bark is known in indigenous medicine for its stimulant and fever-reducing effects; the bark leaves and fruits contain tannins. In the Philippines, a decoction of the leaves, known

Queen's flower

Padeka

by the name *banaba*, has been used to treat diabetes; interestingly, the lowering of blood sugar levels by this decoction has been experimentally substantiated and reported in scientific literature. The leaves are also purgative and diuretic, while the seeds are believed to be narcotic.

Among the ten odd species of the genus *Lagerstroemia* found in India, another tree one sometimes encounters, growing side by side with other deciduous trees in the forest, is the **nandi** tree (*Lagerstroemia lanceolata*). It has been mentioned by this name (*nandi*) in Valmiki's *Ramayana*. Quite unlike the jarul, the nandi lacks colourful showy flowers; its flowers are small and white, disposed in clusters on the extreme ends of leafy branches and often escape notice, especially in tall trees whose canopies are obscured by other trees. Like many other *Lagerstroemiae*, its trunk is smooth and light greyish-brown in colour with thin, long strips of bark peeling off. The nandi flowers with the onset of the rains, and shortly thereafter large numbers of small bullet-shaped capsules develop. Its leaves are somewhat smaller than those of the queen's flower, are rough in texture and dull green; they are often collected to be used as green manure. Nandi wood is strong and elastic and is used for building and other constructional work.

Nandi tree. Inset shows branch with leaves and fruits (photos by S. R. Nayak)

A rather unusual deciduous tree with a wide distribution throughout our country is the **chalta** (*Dillenia pentagyna*). What strikes one on seeing this rather large tree with pale, smooth bark is the immense size of its leaves. Each leaf when full grown is almost one metre or more in length, and about a third as broad; it is pointed and the margins are serrated like the blade of a saw. The leaf is rough and stiff, linear and elliptical in shape, with prominent nerves running from the central rib to end at the tips of the saw-like edges. The leaves tend to be bunched together near the terminal portions of the branches. A sure sign that the chalta grows in a forest is to find its large leaves on the ground, especially in early summer; the tell-tale shape and size of the leaves gives away its presence, for the tree is not too numerous and it is generally not common to find large pure strands of chaltas in a forest; it mostly grows in association with other trees.

Between March and May, the tree is relatively bare, with some new leaves emerging, when the five-petalled, yellow flowers appear in fascicles on the leafless old branches. The chalta flower is about 5 cm across, possesses thick ovate sepals, yellow petals with crinkled margins, and a central cluster of many yellow stamens. The chalta fruits rather profusely in May and June; the fruits, each the size of a table-tennis ball, are edible both raw and cooked, and have an acid-sweet taste. Both the light green raw fruits as well as the orange-yellow ripe ones are a great favourite with monkeys and deer. A peculiar feature of the fruit is that each juicy capsule is enclosed by the fleshy sepals of the calyx which grow and merge with the fruit; it therefore appears to be overlain by broad fleshy ribs; the four or five seeds in each fruit are disseminated through animals which eat the fruit.

The al (morinda). Note the fruit with " eyes " (photo by S. R. Nayak)

The chalta has some economic uses locally; the hard, purplish-red heartwood is used for making house posts, rafters and the like, and sometimes for charcoal; village folk use the large leaves as platters and thatching material, sometimes even as a makeshift sandpaper for polishing; the bark provides a rough fibre for cordage.

The fruit tree mentioned by Valmiki in Sanskrit as *charitra* or *bhavya* is believed to be another species, *Dillenia indica*, with smaller leaves, large white flowers and larger fruits. Its fruit juice mixed with water and sugar is used as a cooling beverage in fevers and cough. *D. indica* fruits are laxative and may cause diarrhoea if eaten in excess. In animal experiments, alcoholic extracts of the leaves are reported to depress the nervous system in mice.

A tree often planted near temples, shrines and tombs, and held to be sacred, is the **barna** (*Crataeva nurvala*). The tree, known in Sanskrit as *varuna* or *triparni*, has been referred to by both Valmiki and Kalidasa. Small to moderate-sized, not usually exceeding 10 to 12 metres in height, its leaves are trifoliate being composed of three leaflets borne on the end of a single stalk; they are shed during the winter and by February the tree is bare; new leaves sprout about a month later. At this time the flowers bloom in loose clusters all over the tree; in some parts of South India the flowering season is from November to January. Barna flowers, unlike most other flowers, have four sepals, and four petals — generally white in colour but quickly turning yellow. A singular feature of the flowers is the large number (about 20 to 25) of stamens, longer than the petals, jutting out of it and surrounding the female part which is itself composed of the ovary borne on the end of a thin stalk as long as the stamens. This ovary (and its stalk) is called a gynophore, and when the fruit develops later towards the close of the rainy season, it is attached to this stalk which has developed from the gynophore. The barna fruit is a round woody berry containing many seeds embedded in a yellow pulp enclosed in a fairly hard shell; the raw green fruit changes to a dark red colour on ripening much in the same way as an apple does.

The sacred barna, also found in the wild state throughout India, is reputed to possess medicinal properties. The leaves are irritant when crushed and rubbed on the skin; this rubefacient action makes it useful (externally) in rheumatism. Internally, the leaves are considered a febrifuge; and many parts of the plant are administered to improve the tone of the urinary bladder and aid in removing urinary stones. Extracts prepared from the bark have shown anti-inflammatory effects in experiments on laboratory animals. The fruit pulp mixed with mortar is known to make a strong cement. Barna wood, pale yellow and close-grained, is employed for making small utility items like combs, matchsticks and the like.

A very well-known soft drink of indigenous origin is *phalsa*, a rich purple coloured acid-sweet beverage made from the small ripe fruits of a plant also known as **phalsa** (*Grewia asiatica*). While this small tree may be familiar to some owing to its wide cultivation, especially in North India, a less familiar member of this genus, the **dhaman** (*Grewia tiliaefolia*), grows rather extensively in the deciduous forests, practically throughout our country.

The dhaman is a medium-sized tree growing to about 10 metres or so in height. During the rains many saplings of the plant may be seen to spring up here and there — identifiable more from the characteristic shape of the leaves than from other features. The leaves are about as large as one's palm (often larger in small saplings) and roughly heart-shaped with one side of each leaf appearing somewhat bigger than the other, thus making it seem slightly curved. Young leaves are a dull red in colour and very furry to feel.

Small, yellowish-white flowers appear in threes and fours in the axils of the leaves from May to August, much after the summer leaf-fall, and the pea-sized fruits develop from June to October. The fruits turn a deep red and then almost black when they ripen. Like the phalsa, dhaman fruits are edible, the pulp being sour and sweet to taste though not as flavoury as those of the phalsa.

Dhaman leaves are used as fodder for livestock. A peculiar feature of the bark (which yields an excellent fibre for rustic ropes) is that it is rich in mucilage which can be extracted by crushing it; this is sometimes used by village women to wash their hair. An interesting use shown to me by a tribal man was the application of the

(contd next page)

" Some game sanctuary you've brought me to ! Not an animal worth the name in sight. "

IN LIGHTER MOMENTS

When the American physicist and rocket pioneer Robert Hutchings Goddard (1882 — 1945), shortly after the First World War, expressed the hope that it would be possible in the near future " to send an unmanned rocket to the Moon " he was badly shocked to find that, apart from some well-meaning personalities of the scientific world, almost the entire press let him down by ridiculing his expectation. However, he got his own back by not calling a press conference in 1926 when he succeeded in firing the first modern rocket — the forerunner of today's spacecraft.

* * *

The American astronomer, Simon Newcomb (1855 — 1909) dared any one to demonstrate in 1906 that " a heavier-than-air machine can ever fly for more than a short distance" — although the Wright brothers had been doing this since 1903. Still later, in the mid-1930s, yet another eminent astronomer of the USA, Forest Ray Moulton (1872—1952), was equally pessimistic when, dealing with spaceships, he wrote : " There is not in sight any source of energy that would be a fair start toward that which would be necessary to get us beyond the gravitational control of the Earth."

* * *

Until the mid-eighteenth century the conditions of even the biggest public hospitals in England were such that, in spite of being free, people were scared of getting admitted there. At St. Bartholomew's, indoor patients were required to deposit in advance 19sh. 6d. as burial fee, to be refunded in case they recovered.

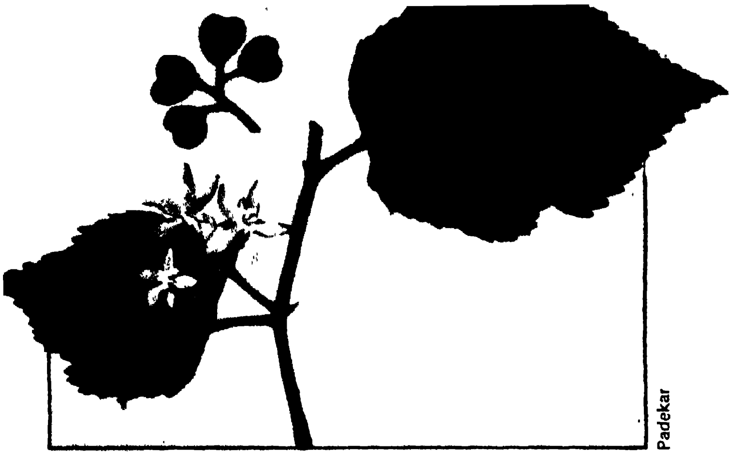
* * *

The number of charlatans and frauds has been greatest amongst chemists (alchemists) and physicians. In 1738, one Mrs. Joanna Stephens made a public announcement that she possessed a sure remedy for stone trouble and could disclose it for £5,000. Collections were launched to raise the fund by a committee of bishops and dukes. Parliament also made a big contribution. When the necessary amount was collected, Mrs. Stephens' secret remedy was announced in the *London Gazette* : " The medicines are a powder, a decoction and pills. The powder consists of egg shells and snails, both calcined. Decoction is made by boiling some herbs (with a base made of soap, Swine's cresses burned to blackness, and honey) in water. The pills are snails calcined, wild carrot seeds, burdock seeds, ashen hays, hips and haws ; all burned to blackness, Alicante soap and honey." Needless to add, it was all bunkum.

* * *

How did the stethoscope originate? Its inventor, Rene Laennec, says : " Taking a sheaf of paper I rolled it into a very tight roll, one end of which I placed over the pericardial region, whilst I put my ear to the other. I was both surprised and gratified at being able to hear the beating of the heart with much greater clearness . . . than I had ever done before."

S. N. MUNSHI



The large leaves and the darkened ripe fruits of the dhaman

Padekar

bark mucilage liberally to the skin when one comes in contact with the severely irritating hairs of the cow-itch pods (*Mucuna pruriens*); its soothing action became apparent within a few minutes.

The hardness and elasticity of the wood makes it suitable for making cart-axles, masts, oars and bent frames for carriages, etc. Bows, too, have been made from dhaman and related trees. Quite appropriately, the dhaman is known in Sanskrit as *dhanuvriksha* (literally, the bow tree).

The **jhingan** or **kimul** (*Lannea coromandelica*), a large deciduous tree with a wide distribution in India, including the Andamans, presents a striking contrast in appearance at two different seasons: during the rains it sports a dense canopy of big oddly pinnate compound leaves and gives the semblance of a truly evergreen tree, whereas in summer, bereft of foliage, it is reduced to a mere black-barked scrawny skeleton.

The small flowers, massed together in fascicles at the ends of the branches, bloom from February to April when the tree is bare. Male and female flowers occur separately on different stalks but on the same tree. The small petals are yellowish-white or purplish. When the oblong, 2 cm long, rather kidney-shaped compressed fruits develop, they hang from the stalks at the farthest ends of the branches — looking like strings of beads hanging from outstretched fingers. The fruit is greenish-grey when raw but becomes dark red when it ripens. Though the scanty pulp is not palatable, and even acrid when raw, the fruits are eaten by birds and monkeys which thus help in dispersal of the seeds.

From the economic standpoint the jhingan tree has some uses: the leaves serve as fodder for livestock; the bark has been used for tanning and dyeing cottons a brown colour; a gum exuding from the incised bark, called jhingan gum, is used in the preparation of inks, for calico printing, in confectionery and making varnishes, and as a flocculating agent. The bark also yields a strong fibre, and its uses in native medicine include application (as a lotion) to bruises, sores, etc. The gum is also believed to be useful in asthma.

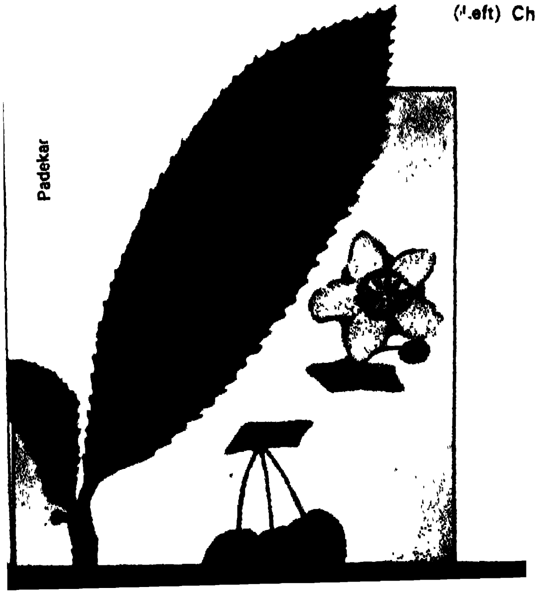
At one time, prior to the advent of synthetic dyes, a red dye used to be extracted, particularly to dye wool and silk, from the root bark of the **al** (or **aak**) tree (*Morinda* species). Two species commonly encountered are: *M. tinctaria* with hairy leaves, a deciduous forest tree, and *M. citrifolia*, with smooth leaves, often grown on the roadside in some cities.

M. tinctaria is a medium-sized tree with a dark, deeply cracked, corky bark. In the field, it can be recognised from the entire, hairy leaves which are disposed in pairs — one of each pair being opposite to the other, and especially during the rains from its characteristic fleshy fruits. It bears small white flowers, with tubular corollae from each of which five petal lobes radiate; the flowers arise from a globose head which later grows and, enclosing the seeds from each flower, becomes the fleshy fruit known as syncarpium. The fruit, about the size of a child's fist, appears roughly angled and globular with "eyes" peeping out from polygonal markings on the fruit (see p. 26). The fruits are not generally eaten except as a famine food.

Al wood is pale-coloured, easily worked and durable, and is used for making plates and dishes. The leaves make good cattle fodder. Though not much used in indigenous medicine, some investigators report that the blood pressure of laboratory animals is lowered by water extracts of its roots.

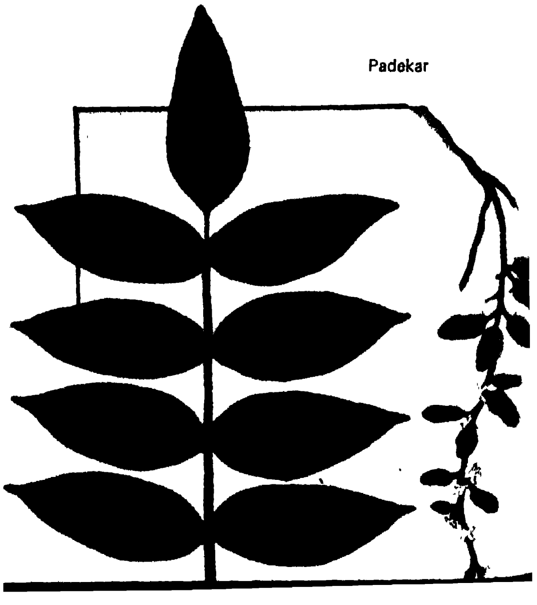
A walk in the woods is very much like passing through a large banquet hall — so much to sample and so many things to taste in the short while one is there. After satiating ourselves while the going is good, should we be thoughtlessly clearing the tables unmindful of yet others who may pass that way and sample the fare?

S. R. AMLADI



(Left) Chalta

Padekar



(Right) Jhingan. The former botanical name *Odina wodier* was derived from the Malayalam *odiya maram* and the Tamil *wodier*

Padekar

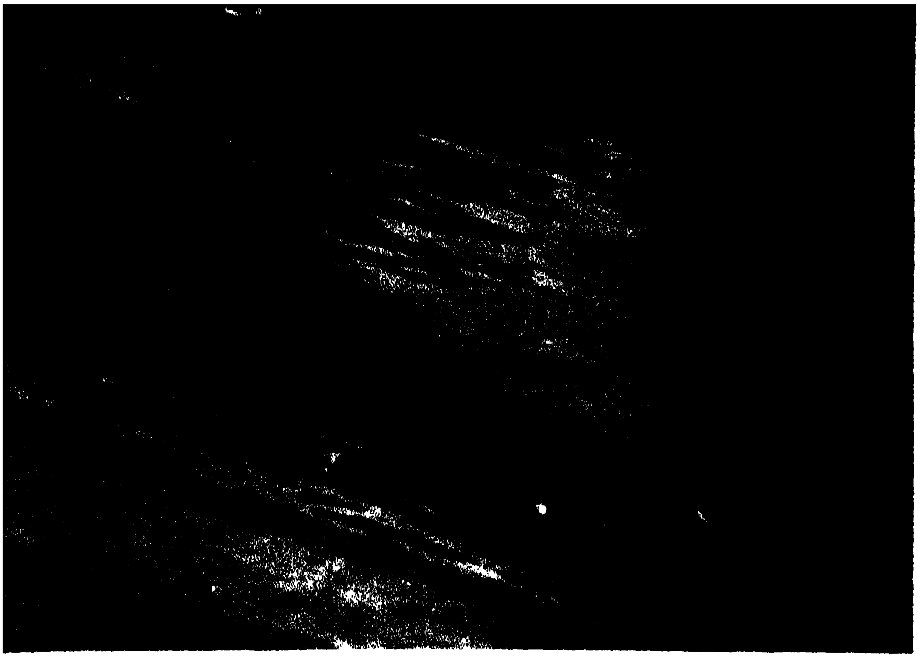


Fig. 1 (Top) A female adult gharial

ON BREEDING CROCODILES

M. V. SUBBA RAO

In January this year, a 50 cm suitcase made of crocodile skin was sold for Rs. 12,000 in London. The skin had come from an estuarine or saltwater crocodile, probably killed for that very purpose; it had probably come from India, which would mean one less of this fast dwindling animal species.

It would be a pity if crocodiles were to disappear from the earth. They began life on this planet 140 million years before man; today their habitat, already shrinking, is confined to a few pockets on the earth. Crocodiles, alligators and caimans — all belong to the same family Crocodylidae or Loricata. Crocodiles are distinguished by their narrow snouts with a notch near the front on both sides into which fit the two large lower teeth; these can be seen when the jaws are closed. The Indian 'gharial' with a very slender snout is a close relative. Alligators, which belong mostly to the Americas, have broader snouts and their large lower teeth fit into sockets inside the upper jaw. Caimans, which are distributed only in the South American continent, have a more oval, blunt and triangular snout.

In all, there are about 22 species of crocodiles living on the earth; of these, only three are found in India and all three are on the endangered list now. These are the *Gavialis gangeticus*, commonly known as the gharial (also gavial), *Crocodylus porosus* or the saltwater crocodile, and *C. palustris* which has the common name mugger or marsh crocodile. Basically a fish-eater, the gharial (the name comes from the *ghara* or the earthen pot-like structure at the tip of the male animal's snout) is a timid animal with a pair of greenish cat-like eyes and an enormously elongated snout; both the upper and lower jaws are studded with sharp, stout, close-set teeth. An adult gharial may grow to nine metres in length — the longest amongst all living crocodiles.

The mugger, too, is a timid animal with gaping jaws and is known to scamper for shelter at the sight of man. Mainly an inhabitant of marshes (hence the common name 'marsh crocodile'), it is the smallest of the three Indian crocodiles. The saltwater (or estuarine) crocodile can grow up to six metres in length and is not a timid animal. The species is easily recognised by a prominent ridge in front of each eye.

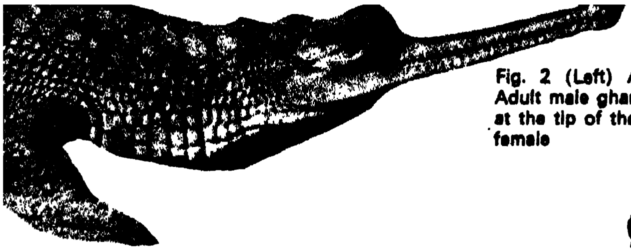
We have said crocodiles are a dwindling species in India. The chief reason for the depletion is perhaps the high price their skins fetch in countries abroad. Two-and-a-half centimetres of belly skin is priced at something like Rs. 40, which means a 3·6 metre long crocodile can easily fetch about Rs. 900 — a fortune to a poor fisherman or a poacher. Besides poaching, crocodiles are also killed in many places because, being carnivorous, they are apt to prey on waterfowl and cattle. Occasionally, a member of the larger species may eat a human being or two, but this happens so infrequently that it would be wrong to regard crocodiles as man-eaters. Possibly the mistaken belief had arisen after fishermen had cut open killed crocodiles and discovered human remains in the stomach; in all likelihood, the crocodile had eaten a corpse thrown into the river.

Sometimes crocodiles are killed by fishermen when they get caught in their fishing nets. In 1967, when crocodiles were found to eat the commercial riverine fish in the Sirsi reservoir, the State government issued a contract for all the crocodiles in the reservoir to be killed.

This is a pity. Crocodiles usually feed on big predatory fishes which in turn prey on smaller commercially valuable species. Thus, they are actually helpful to fisheries and do not deplete fish populations as popularly believed. Indiscriminate slaughter of the crocodile has in fact caused ecological imbalances in several parts of the world. For instance, the disappearance of the Nile crocodile (*C. niloticus*) from parts of Africa has resulted in an overabundance of the catfish *Clarias* which in turn has greatly depleted the supply of fishes good for human consumption.

Several countries including India have, by legislation, tried to save the crocodile. In India, both the mugger and the gharial were declared protected species in 1958. Killing, trading, exporting or possessing of crocodiles has been banned under the Wildlife Protection Act of 1972. However, it has come to be recognised that if the original balance is to be restored, crocodiles must be bred and raised on farms. But how does one go about this stupendous task?

The answer was a project started in late 1975 with UN assistance for restocking suitable stretches of rivers, tidal mangrove swamps and reservoirs with Indian species of crocodiles. Today, besides two model sanctuaries in Orissa and Andhra Pradesh, crocodile farming is also afoot at UP, Rajasthan, Tamil Nadu, Gujarat and Kerala.



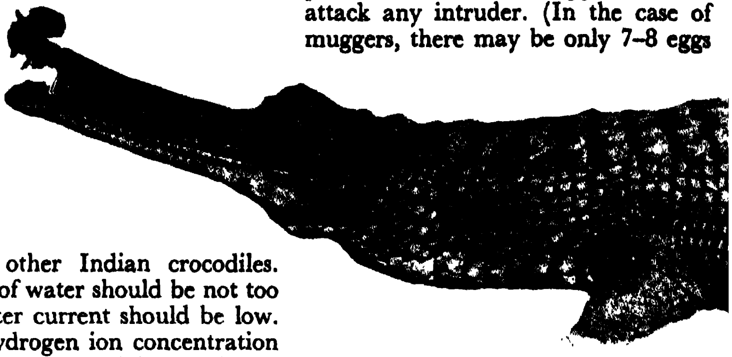


Fig. 2 (Left) Adult female gharial. (Below) Adult male gharial. Note the pot-like structure at the tip of the snout which is absent in the female

In this article, we shall talk about what we have learnt from our work over the past two years at the farms set up in Orissa. There is a significant reason behind our choosing Orissa as a model site: Orissa happens to be the only State in India which has all the three Indian species.

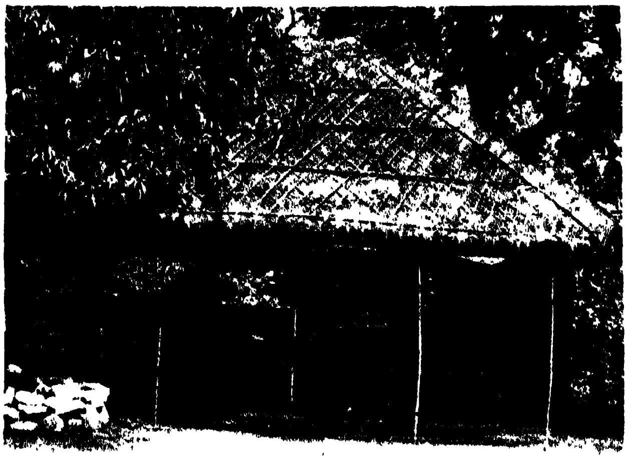
Crocodile farming

There are two types of crocodile farming practised all over the world. One is battery farming, the other, free range management.

Before coming to the subject of artificial breeding, a brief note should be made about the life-cycle and mating habits of these animals. Crocodiles mature within three to four years after they are born. Mating takes place from the fourth year onwards — during winter (December to February). The mating behaviour is influenced by several external factors. The depth of water should be about nine metres for gharials and two metres for other Indian crocodiles. The colour of water should be not too muddy, water current should be low. As far as hydrogen ion concentration is concerned, it should be acidic for gharials and muggers, but alkaline for the saltwater species. (All the above conditions are maintained for induced mating in breeding farms.) Mating occurs in water, lasts for about 10 minutes, though there is a longer preceding courtship in which the animals rub their muzzles against each other.

The sexes can be distinguished externally only in the gharial in which the males, during the reproductive period, have a bulbous knob at the tip of the muzzle (Fig. 2). The gharial's nest is merely a hole in the ground dug at night by the female with her hind feet. According to the size of the female, she lays 20–90 eggs only once in a year. She covers the hole to ground level and slides back to the water. The female is extremely protective about her eggs and will attack any intruder. (In the case of muggers, there may be only 7–8 eggs in the first breeding year; in prime laying years, the average may be around 40–45 eggs.) The temperature in the nest is between 31° and 34°C and, at times, the mother may lie over the egg pit to warm it up.

As the hatchlings emerge, they make periodically short, barely audible grunts which are signals for the mother to pick them up from the ground — with her front teeth and jaw — and take them to the water. Unlike birds or hens, mother crocodiles do not help their young find food. Immediately after hatching, the young ones are about 30 to 35 cm long and



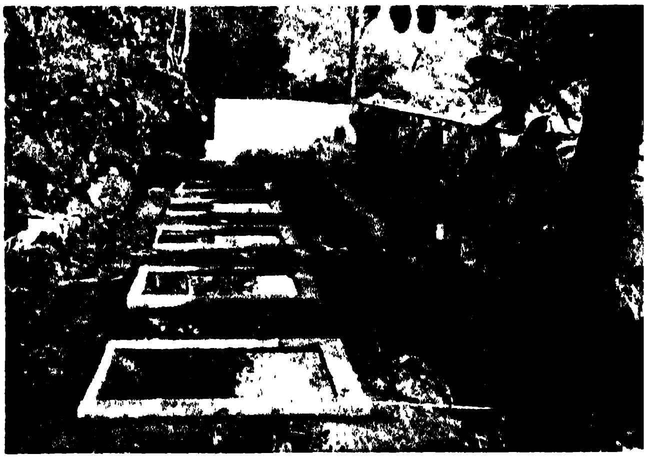
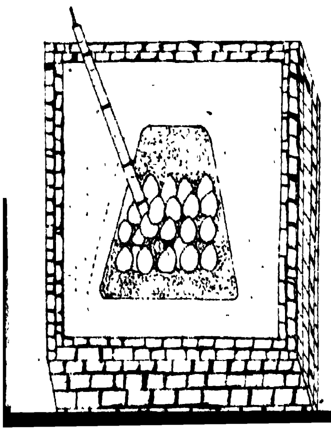


Fig. 3 (Above) Gharial hatchery. (Below) Diagram of the moist sand-filled artificial incubator. The bamboo pole is used for introducing a thermometer

Fig. 4 (Below) Primary gharial pool. There are 10 pools completely covered by a wire mesh. "Second-year pools" (not shown) have larger dimensions. Photograph above shows one side of the pools under construction



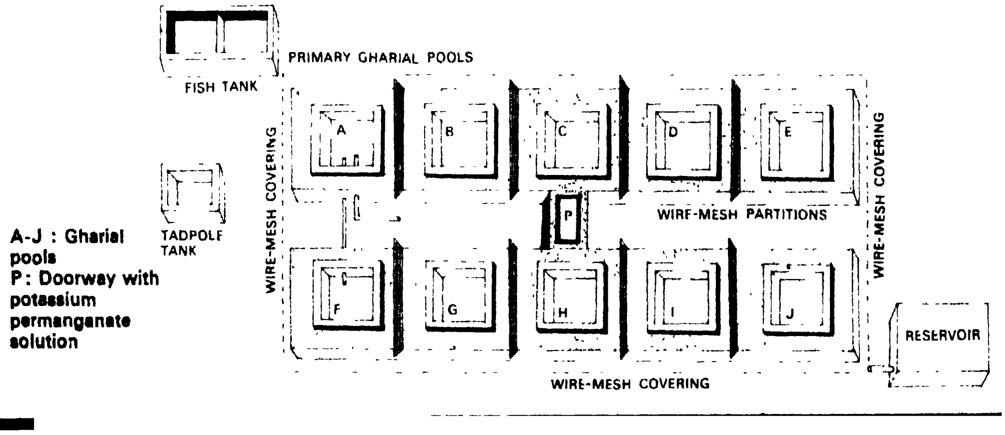


TABLE 1: DISTRIBUTION OF GHARIALS IN THE WILD AND IN CAPTIVITY

1. In the wild (estimated number) in India	
Girwa river (UP)	22
Chambal river (UP, MP, Rajasthan)	50
Assam rivers	10
MP rivers (other than Chambal)	10
Gandak and Kosi rivers (Bihar)	6
Ramganga river (UP)	4
Mahanadi river (Orissa : 2 males, 2 females)	4
Total	106
2. In the wild (estimated number) in Nepal	
Kosi river	20
Narayani river	17
Karnali river	8
Babai river	6
Total	51
3. In the wild (estimated number) in Pakistan	
All rivers	20
4. In captivity	
Indian zoos	22 (10 males, 12 females)
International zoos	15 (sex distribution not known)

[Source of information *Zoo Yearbook*, *Newsletters*, Madras Crocodile Bank, and personal correspondence, etc.]

weigh between 60 & 90 grams. Growth is very rapid in the early days — 6·5 to 7·5 cm per month — though later the growth rate slows down.

The first two years after birth is the most vulnerable period in a crocodile's life. The predators — monitor lizards, wild dogs, cats and birds of prey — may attack during and after hatching. Also, young crocs caught in fishermen's nets are invariably killed.

Most of the information available on the longevity of crocodiles has been gained from observation of animals in captivity. The life-span of a crocodile in captivity seldom exceeds 40 years, but statistics on the growth of the Nile crocodile suggests, however, that those who have attained lengths of six metres are probably more than 100 years old.

Coming back to farming, how are the eggs collected? The first step is to keep a watch on the egg-laying sites (with the help of fishermen and tribals). Mating in gharials generally takes place in January–February, and the eggs are laid by March–April and these hatch in June–July. After a nest has been located, the eggs are collected carefully by hand and kept in ventilated wooden boxes filled with damp nest earth after marking the top of each egg with Indian ink. If the egg is turned or jarred, the delicate embryo is likely to die. Care is taken to collect them during the cool part of the day as a drastic temperature change would be harmful. (In Orissa this sometimes poses a problem as summer shade temperatures are as high as 46° to 47°C. Large natural sand banks, however, maintain the required temperature even on hot days.)

After collection, the eggs are housed in a specially constructed hatchery fully covered by wire (Fig. 3). The only access to the enclosure is through a trap-door on the roof. The whole structure is covered by a thatching to provide shade. Eggs are placed in a hole in a cubic metre of slightly moistened sand (about seven per cent water content by weight) held in place by side-walls made of half bricks; this allows passage of air causing an evaporative cooling effect as in an earthenware water pot. The degree of cooling can be controlled by the amount of water added to the nest mound daily. The gharial eggs are maintained in three layers at the centre of the hole — each of 22, 10 and 8 eggs, respectively. A thermometer introduced through a thin bamboo pole records the temperature which is maintained at a steady 30°± 0·5°C by sprinkling the sand with six to eight litres of water every day during the summer — the water regime has been worked out to keep the eggs slightly on the cool side.

The young ones, immediately after hatching, are kept in the " first-year pools " (Fig. 5) for about one year. The first-year pools have dimensions of 2·13 m × 2·28 m, with a sloping depth from the pool edge to a maximum of 0·3 m. Each pool, separated by a 0·3 metre high wire mesh, is surrounded by clean river sand containing living *Salix* for the young gharials to bask in the morning and evening Sun. Large-leaved plants such as *Cycas* are allowed to overhang the pool for additional cover. In winter the roof is covered with polythene as protection against cold. A fast-growing creeper (*Antigonium*) and palm-leaves (*Borossus*) are also tied to the roof in an irregular pattern to provide a sunshine mosaic. Each set of five pools is connected to another set by a cemented 2·5 cm deep path which contains dilute potassium permanganate solution. Any person wishing to enter must step into the solution first. The permanganate acts as a disinfectant. The ten gharial pools are covered by a wire mesh. There are tanks for fish and tadpoles, for the baby gharials to feed on. Baby gharials do not take food for about five days after emerging from the eggs; their nutrition comes from the absorbed yolk-sacs. About 250 to 350 scaleless live fish (not generally consumed by man), 2·5 to 3·5 cm in length, are let into the tank every day. When feeding starts, baby gharials are found to be initially clumsy at catching their prey.

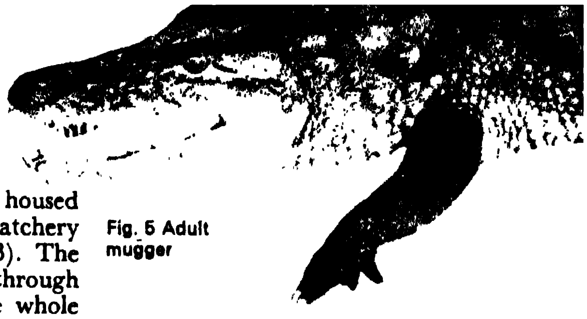
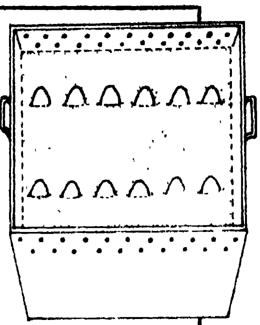


Fig. 5 Adult mugger

The problem of transporting eggs



For battery-breeding, eggs need to be transported to the hatcheries from nests discovered along marshes or river banks, some located long distances away from the breeding farms. This requires expert handling. The ventilated wooden box (shown above) is the best possible arrangement at present. Measuring 50 × 40 × 30 cm, these are fitted with handles for carrying by 2 to 4 persons. Each box can hold 12 eggs, packed in moist nest earth.

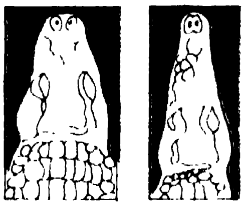
Yet the prized eggs do get destroyed. For instance, last year, 236 eggs were collected from the Narayani river in Nepal, some from fishermen who were carrying them in their boats to take home and make omelettes. The eggs were brought to Patna by Land Rover, then to Cuttack by rail and then another 190 km to Tikerpara by Orissa State Forest Jeep. Less than a hundred survived (that is, 60 per cent mortality). The mortality rate depends mainly upon the size of the egg, the movement of the egg during transit and also the hatchery conditions during the incubation period. Interestingly, Dr. H. R. Bustard brought 10 one-month-old baby gharials from Lucknow to Bhubaneswar by air in a single small air-bag and all 10 are growing healthily at the Tikerpara gharial pool.

Below: The author (left) with Dr. H. R. Bustard, FAO expert on crocodiles and sea turtles

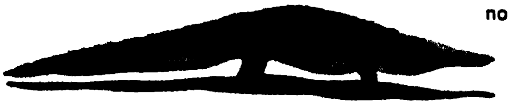
SOME NON-INDIAN CROCODILES

(Below) American crocodile *(Crocodylus acutus)*

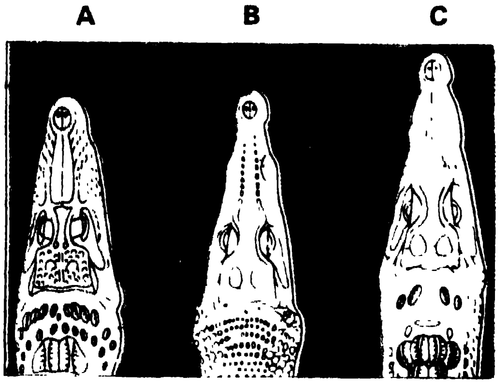
(Left) American alligator *(Alligator mississipiensis)*



Above: Head of alligator (left) and of crocodile (right). The alligator has a broader and rounded snout with the nostrils placed slightly apart



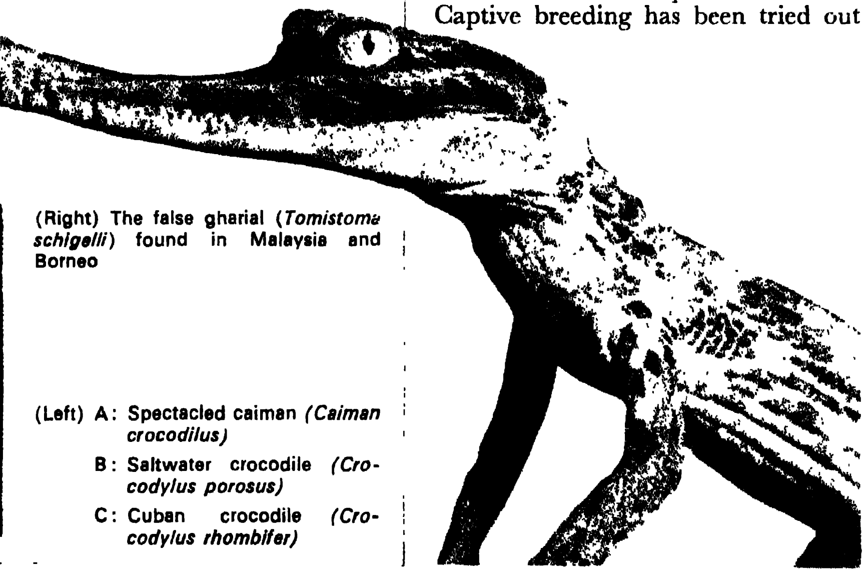
The Nile crocodile



(Left) A: Spectacled caiman *(Caiman crocodilus)*

B: Saltwater crocodile *(Crocodylus porosus)*

C: Cuban crocodile *(Crocodylus rhombifer)*



(Right) The false gharial (*Tomistoma schlgelli*) found in Malaysia and Borneo

Thus, unless the conditions are suitable and food is available in sufficient quantity, the young may perish. Once feeding has commenced, tadpoles, too, are offered on alternate days.

As the young increase in size, the size of the fish offered is also increased. After 3–4 months, the baby gharials are given, in addition, one small white rat each, once a week. Growth at this stage is rapid, at the rate of about 7·5 cm per month.

Each pool accommodates 10 to 12 crocodiles. They always remain in groups. Gharials never fight with each other for food, whereas muggers are notorious for this.

The secondary pools for the one-year-old gharials have dimensions of 4·6 × 4·6 × 1 m. Each pool is surrounded by about 1 m width of sand, 15 cm deep. Gharial hatchlings grown to a size of about one metre are reared in these pools for about another year before they are let into the Satkosia gorge of the Mahanadi — once considered the last stronghold of the gharial. But relentless slaughter has made them almost extinct even here. One great reason for the depletion of the gharial population here was the introduction of commercial fishing. Fishermen would kill them not only for skins, but also whenever they got entangled in their fishing nets, in order to save the nets. (The Government of Orissa has issued nylon nets to the fishermen which are put across daily within the gorge.) Today, the Satkosia gorge has only four adult gharials left; two males with lengths of about 7 m and 5·5 m, and two females with lengths of about 4·6 m and 3·4 m, respectively.

In *free-range management*, the crocodiles of an area, which could be a lake or a reservoir, or a section of a river or a tidal creek, are managed *in situ*. All the stock, or the young ones being grown to become future breeding stock, are freely ranged. Stocking rates are adjusted to a range of environmental parameters including food supply. In this method the housing costs are eliminated. The aims are two-fold: (*i*) to ensure the conservation of the crocodilian species, and (*ii*) to build up an export industry with maximum foreign exchange earnings from crocodile leather.

Economists estimate that once the Satkosia gorge is restocked, the annual profit from skins alone will be as high as Rs. 1,500,000. Crocodile meat which is a delicacy in countries like Japan, may also fetch about Rs. 40 per kg.

This is not an optimist's dream. Captive breeding has been tried out elsewhere and one of the rarest species, the African dwarf crocodile, was bred in captivity for the first time this year in Zoo Negara in Malaysia. Perhaps the most successful — a commercial venture for skins — is the famous battery crocodile farm at Samut Prakan in Thailand, said to be the

BREEDING CENTRES IN INDIA

Gavialis gangeticus (gharial): Satkosia gorge, Tikerpara, Orissa, and Lucknow, UP.

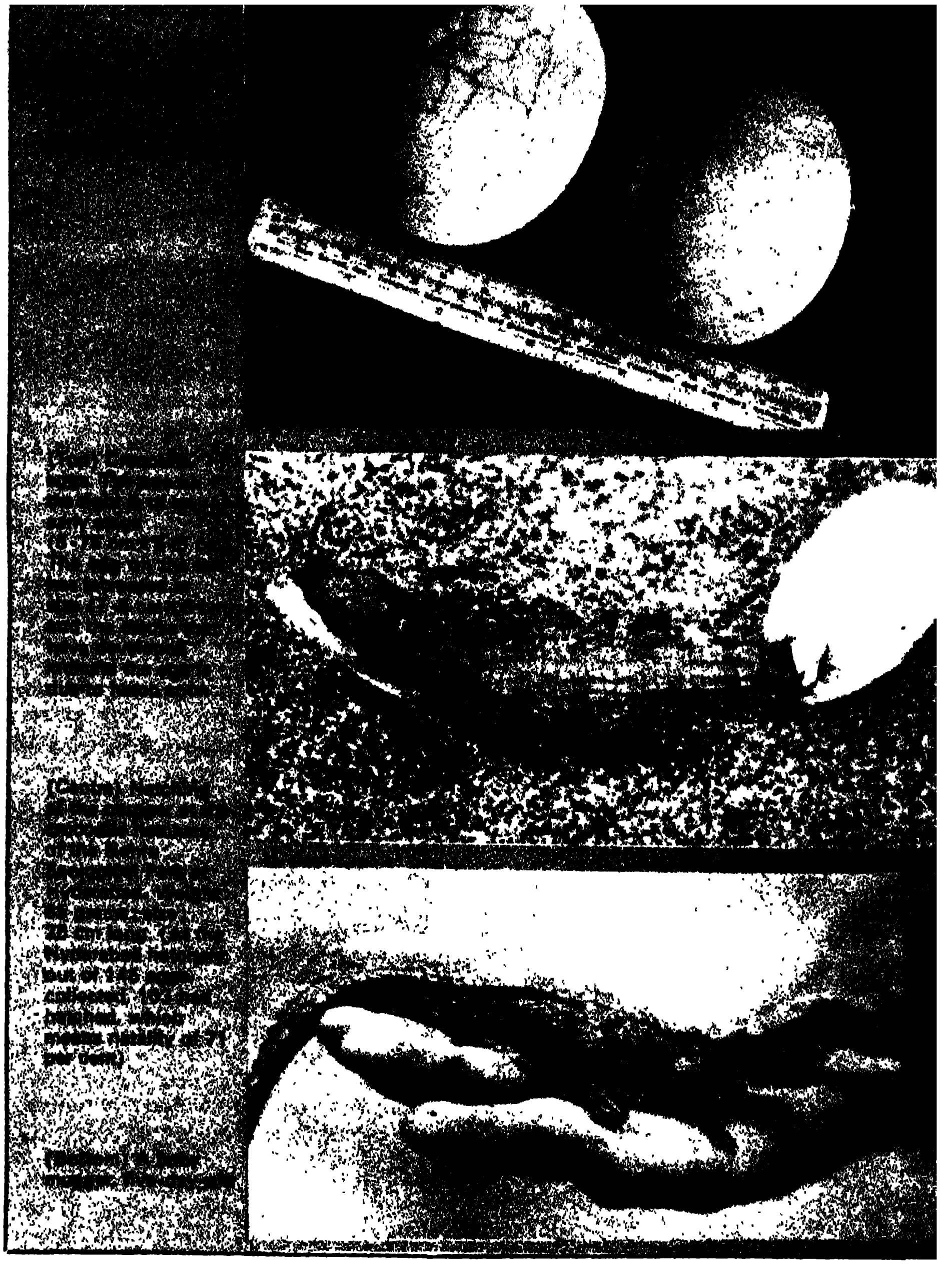
Crocodylus porosus (saltwater or estuarine crocodile): Bhitarkanika in Orissa and Kakinada estuary, Andhra Pradesh.

Crocodylus palustris (mugger or marsh crocodile): Madras Snake Park, Guindy, Tamil Nadu, Nagarjunasagar area in Andhra Pradesh and in Gujarat.

world's largest. Started in 1950 by Uthai Youngprapakorn with just 20 wild crocodiles and a capital of $500, last year the farm had 18,000 crocodiles that put the farm's worth at about $2 million.

In India, the preservation of the seriously threatened crocodile population received attention for the first time in May 1974, after the visit to India of FAO expert Dr. Harold Bustard. And since the sanctioning of the first crocodile farm in Orissa, there has been much activity all over the country. Attempts to breed have been successful at many centres. By January 1977, 120 gharials were hatched in Orissa alone. The five-year project for breeding and management of crocodiles, started with UNDP assistance, is managed by the FAO (in collaboration with the Ministry of Agriculture) and has its headquarters at Hyderabad with training centres at Lucknow and Hyderabad. When the project started in late 1975, there were only 60 to 70 gharials in India; within a year 450 baby gharials were reared. At present, some 1,400 gharials are growing in various sanctuaries — Satkosia gorge in Orissa, Chambal river in Rajasthan, Katernaia Ghat in Bahraich District in UP. More interestingly, seven PhD scholars are working with Dr. Bustard along with 1,500 tribal workers.

One last point. While preservationists are chiefly concerned about giving the dwindling species a chance to live and proliferate, any small success in the breeding operations anywhere in the country immediately sparks off ambitious estimations in the government departments as well as in the press about the "returns" that will start flowing in after crocodile populations have reached a viable number when they can be killed for exporting skin and meat. This is not a healthy attitude. The primary aim at the moment should be to preserve the species alone and not in counting financial gains earned from killing before the crocodiles are even hatched.



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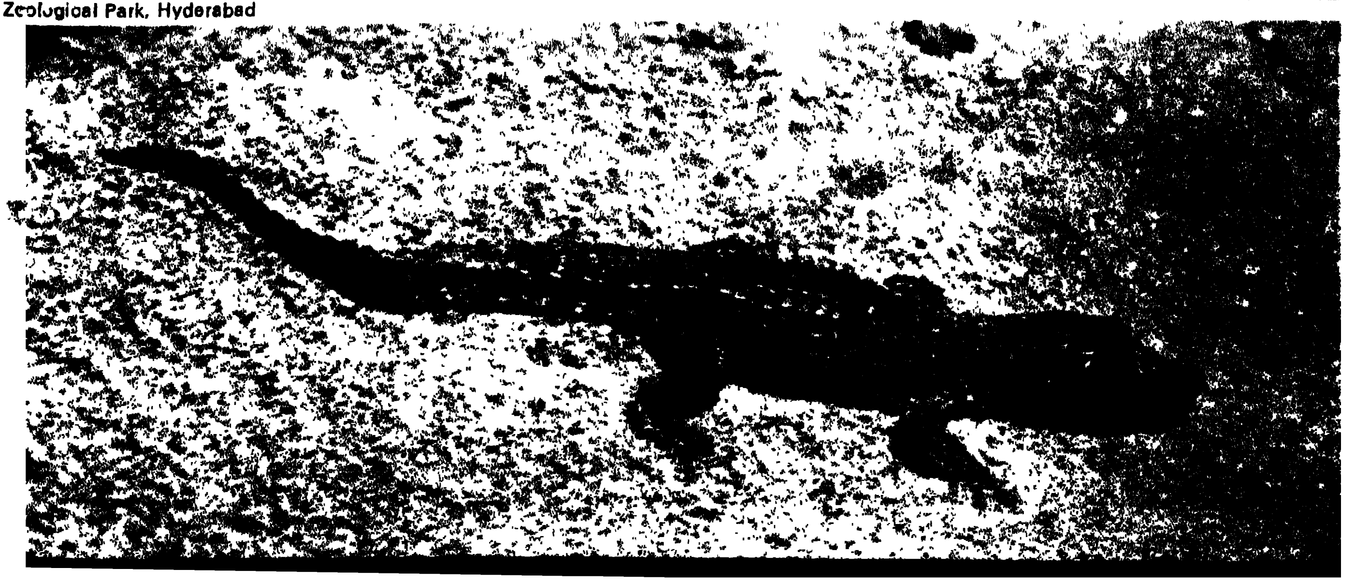
Dr. Subba Rao teaches ecology and physiology at the Post-graduate Department of Zoology, Utkal University, Bhubaneswar. He is a member of the Integrated Crocodile and Sea Turtle Project of the Government of Orissa.

Fig. 6 Three-day-old mugger hatched last June at the mugger hatchery of the Nehru Zoological Park, Hyderabad



A non-scaling column for alcohol distilleries

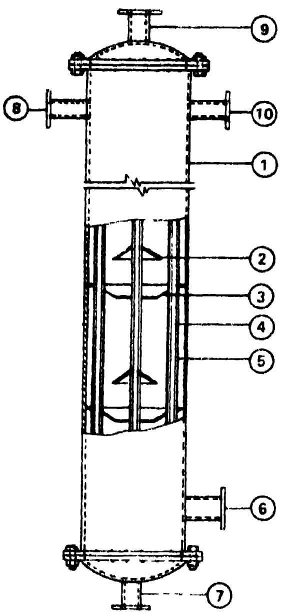


Fig. 1 Non-scaling distillation column. 1. Shell 2. Disc 3. Doughnut 4. Tie rod 5. Spacer 6. Vapour inlet 7. Reboiler 8. Feed inlet 9. Vapour outlet 10. Reflux inlet

Scaling is one of the major problems encountered in the chemical process industry in general, and in alcohol distilleries in particular. Due to water hardness, scales form on the tubes of the evaporator; this lowers its heat and mass transfer capacities. In the alcohol distillery, scaling occurs on the plates of the analyser column with the formation of a hard crystalline mass (scale) consisting mainly of calcium sulphate and other salts. The scales are extremely hard, varying in thickness from 1·5 cm to 5 cm. There is a gradual reduction of the capacity of the column, since the scales choke the holes of the vapour ports of the column, resulting in a low turn-down ratio and, finally, shut-down of the plant for cleaning the trays. Scaling reduces the overall profitability of the unit.

A non-scaling distillation column designed and fabricated in the Regional Research Laboratory, Bhubaneswar, is shown in Fig. 1. The column can replace the existing analyser column in alcohol distilleries. In the column, plates of slanted discs and doughnuts are mounted on tie-rods alternately in the form of a cartridge, facilitating easy insertion into the column (Fig. 2). The doughnuts are provided with suitable gaskets on the periphery to form a tight seal against the column shell, preventing leakage of the vapour. The main design criterion for the tray is that the high vapour velocities are created so as to impart vibrations to the thin plates of the discs and doughnuts. These vibrations make the scale deposits slide down the slanted surface of the plates, and these finally exit through the central hole of the doughnut. The formation of scales of the plates is thus prevented.

The column was tested with a synthetic solution of dilute alcohol as the feed. Calcium sulphate was mixed into the feed as the scaling agent. The feed was heated to about 70°C and then introduced into the feed tray of the column. Live steam was injected from the bottom of the column. Stripping of alcohol from the dilute aqueous feed, along with the calcium sulphate, was studied. After prolonged operation of the column, the plates of the column were removed for inspection and analysis. There was hardly any deposition of the scale on the plates.

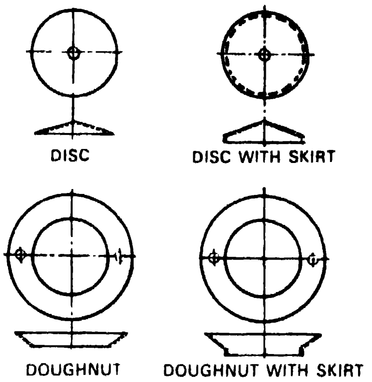


Fig. 2 Details of baffles

Although the relative efficiency of the type of tray used in the column is low, the cost of the tray is much less than that of other trays. The design of the column is covered by an Indian patent.

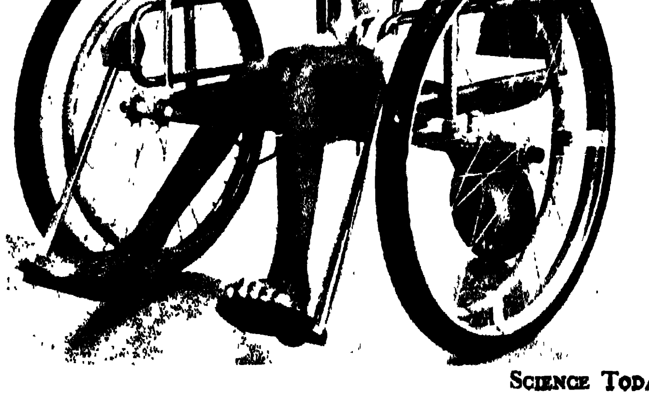
A. RAMAKRISHNA RAO
K. MADHUSUDAN RAO

[The authors are with the Regional Research Laboratory, Bhubaneswar.]

Wheelchair for the disabled

While there are many problems of the able-bodied demanding immediate attention, the handicapped minority, whose number is steadily increasing, has remained relatively neglected. To the disabled, what hurts most is their dependency on others for simple daily activities, and the attitude of sympathy and pity.

A physical aid, therefore, plays a crucial role in the lives of the disabled. And for those whose lower limbs are incapacitated, the wheel chair is a convenient device to sit on and move about. The existing wheelchairs in our country are, however, heavy, expensive and unwieldy. They usually have a hard seat which transfers the jerks and shocks from the undulated ground to the thighs. The four small castor wheels make it very difficult to go over ditches and other obstacles; turning is also a little difficult. Some chairs are foldable, but as there is no locking arrangement, the chair tends to fold with every jolt.



The wheelchair for the disabled designed at the National Institute of Design, Ahmedabad

All main structural members are pivoted to a single point to facilitate folding of the unit. So, the whole weight of the occupant acts on this single pivot point, making the chair structurally weak. The back rest and the foot rests are fixed, and not adjustable for people of various heights and physical builds.

Besides, most of the wheelchairs do not have hand-rails for wheeling, which means dependency on someone else for moving it or handling the rolling wheels which carry dust from the ground. The foldable wheelchairs have a canvas seat, but as the frame is not rigid, in actual use the seat becomes uncomfortable.

Unlike ordinary chairs which are used at a fixed place for a definite function, a wheelchair has to carry its occupant from place to place to perform different tasks. Almost all existing wheelchairs seem to overlook this important aspect. They do not, for instance, take into consideration the height levels of the sanitary fittings in Indian homes. Even our best wheelchairs are still those which were given as aid or imported. They do not suit well the social, psychological and physical requirements of the Indian user.

These were the considerations behind the design of a new wheelchair at the National Institute of Design (NID), Ahmedabad. The chair is constructed in lightweight mild steel tube to be strong as well as stable and less prone to vibrations. It has three wheels, instead of four. The two main wheels are standard bicycle wheels, whereas the third, supporting wheel in the rear is a standard castor wheel. A large-size castor wheel of 20 cm diameter is chosen to facilitate easy movement on uneven ground. The single castor wheel provides a better turning facility within a 40 cm radius. This rear wheel is attached to the body with a cantilever which gives a suspension effect and absorbs normal shocks and jolts. The rolling noise of the wheels has also been considerably reduced.

The seat and back rest are designed as a single detachable unit; this helps the transfer of the person, particularly if he/she is a child. This unit can also be used as a seat for writing, reading, etc (see figure in next column).

The single unit has a rigid frame fitted with a comfortable leather seat which could be tightened whenever necessary. The seat itself could be attached to the body at different levels to suit different users, a child or an aged one. The minimum level is kept at 36 cm to match the height of the Indian toilet seat, so that the transfer is easier.

An important feature is that the chair has detachable foot rests which could be adjusted to suit the user's resting requirements. The wheelchair also folds into a more compact size than the existing chairs for convenient storage and transport in buses, trains, etc. The unfolding is lockable. The wheeling hand-rails are made of cane, which is lighter and cheaper.

The design was developed after a close study and continued dialogue with disabled persons at the Apanga Manav Mandal at Ahmedabad. Reactions from inmates who tried the prototype were quite positive.

This chair could be produced by a smallscale unit. Standard components like pipe joints, tubes and standard bicycle wheels are used to reduce the cost. When mass produced, the cost is estimated to be 30 per cent lower than that of the existing wheelchairs. The wheelchair is not presently being produced by the NID or anyone else. A second prototype from the production feasibility point of view is being designed at the NID workshop.

S. BALARAM

Immobilised enzymes

Enzymes are well-known as catalysts. They facilitate reactions of highly complicated chemistry. But a problem in enzyme-catalysed reactions is the recovery of the enzyme. Since enzymes are used in very low concentrations, their recovery is not possible.

A technique to keep the enzyme in the reaction system and still make it easily recoverable is to immobilise the enzyme — by physically or chemically bonding it to a polymer substrate which does not react with the reactants. The enzyme can be separated by filtration after the reaction is complete. Substrates such as polymer fibres, hollow spheres or solid particles have already been reported. A relatively new substrate is a cellulose derivative, modified to reduce the hydrophilic nature of cellulose. Adsorption of the enzyme on the modified cellulose takes place specifically on the newly formed hydrophobic surface (*Chemical & Engineering News*, **55,** 22–23, 1977).

The polymer, phenoxy acetyl cellulose, is prepared by reacting phenoxy acetyl chloride with cellulose suspended in a 1 : 1 mixture of pyridine and dimethyl formamide at 70°C. After standing overnight, the supernatant liquid is decanted and the product is purified by several washings with ethyl alcohol. The compound can be stored dry. In aqueous media, however, it slowly hydrolyses. To bind the enzyme, a solution of the enzyme is passed through a column packed with the modified cellulose. The cellulose binds about 0·3 to 0·5 per cent of its own weight of enzyme, which retains a high activity. The activity of enzymes bound in this way will be higher than those bound by conventional techniques of inclusion of enzyme in a polymer or a gel where only a small portion of the enzyme is exposed to the reaction.

Though the practical applications of the technique are still to be established, the possibilities are quite wide. Cellulose is available in several forms — fibre, thread, sheet, cloth or powder. All of these may be used, depending on the amount of the enzyme needed and its contact time with the reactants; for example, enzyme-treated filter paper can simplify the clarification of juices. Enzymes immobilised on phenoxy-acetylated strings can simplify analytical and clinical procedures now performed with soluble enzymes. If the enzyme activity is standardised per unit linear measure of the string, unskilled workers can measure out and use precise amounts of the enzyme just by taking out the right length of the string. The enzyme can be added to, or removed from, a mixture without otherwise affecting its composition, merely by inserting or pulling out the string.

Besides, the new technique can help make several interesting products. If a cloth is made from derivatised fabric bonded with an enzyme, a self-cleaning cloth will result. Cellulose enzymes bound to derivatised cellulose could lead to self-dissolving packaging materials. And wound dressing made with gauze treated with proteolytic enzymes can promote quicker healing.

V. C. MALSHE

Padekar

DiAMONDS

M. L. DESHPANDE

It's an old Persian legend that says, when God made the world, he made no "useless" things like gems. It was the work of Satan, who took the colour, lustre and beauty of flowers from the Garden of Eden (which Eve so loved) and hid them in the earth as gem stones — emeralds, sapphires, rubies, diamonds, — so that the evil of avarice would be perpetuated through time. The lure of gems, particularly diamonds, may not be entirely satanic, but there is indeed something of the magical about it, since, in every phase of recorded history, people have associated them with both good luck and ill fortune, paid fabulous sums, fought wars, killed or adopted other devious means to possess them.

Few of us are aware that a diamond retrieved in the ' rough ' is still a long way off from the cut and polished gems that are put up for sale with price-tags of four, five or still larger digits. The reason, for one, is that to produce seven tonnes of diamonds, over 150 million tonnes of diamondiferous ore must be hauled to the surface and processed. For another, the " cutting " is so tricky that a single careless cleavage can shatter a large piece into worthless splinters. And, then, there is the question of colour (or its absence), inclusions and flaws that determine the price of a gem diamond.

Before we proceed further, it must be made clear that diamonds are not all that " useless " as the legend quoted earlier says. Today, they are an invaluable aid in industry (for use in cutting tools and a host of other industrial applications) and, besides, the non-gem diamond pieces are themselves used in cutting and polishing the gem ones. Behind all this, there's a simple reason: diamonds are the hardest material known to man.

What is a diamond

Believe it or not, a diamond is nothing but a crystalline form of pure carbon. And strangely, its closest relative is graphite, the ' black-lead ' of our pencils, which is the other crystalline form in which carbon occurs in nature. It must have been one of nature's whims that fashioned these two — the soft, greasy graphite, so soft that it can be used as a lubricant, and the hard diamond, which is indeed so hard that it can be cut with only another diamond.

This hardness of the diamond is due to its atomic structure. Each carbon atom in diamond is bonded to four neighbouring carbon atoms so closely and symmetrically that it is almost impossible to press the atoms any closer than they are. No wonder diamond has a density 3·5 times that of water.

We still do not know for sure how diamonds came to be formed in the earth. But the assumption is that diamonds crystallised from carbon at a depth of about 160 km, where both the pressure and temperature necessary to transform graphite carbon into diamond exist.

If a diamond is heated to, say, 1200°C, it slowly converts to graphite. The transformation becomes catastrophic if the temperature is raised to about 1900°C. For instance, between the carbon poles of an electric arc, diamond is converted to graphite. The graphitisation can, however, be arrested by increasing the pressure around the diamond. Conversely, if graphite is heated to, say, 2500°C and then a huge pressure is applied (at least 100,000 atmospheres), it can be transformed into diamond. Provided the temperature cools down before the pressure is released, the diamond, once made, stays put. Probably, this is how diamonds grew in the earth.

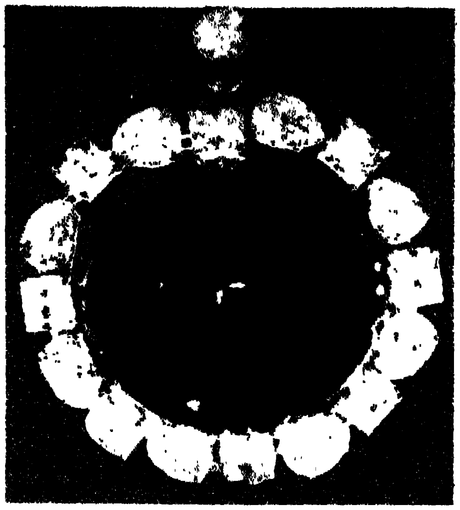
How did the diamonds, formed at such great depths, reach the surface where they are usually found? Here, too, the presumption is that they were forced up from below during geological upheavals, encased in very deep, cylindrical-shaped pipes now called kimberlites, meaning " blue ground " (from its colour). The movement seems to have been mainly a matter of pressure, as there is no evidence that the pipes had been exceedingly hot on their way up. A typically ' large ' pipe is usually of oval shape and can be as much as a kilometre across.

Diamonds also occur in alluvial deposits, river-beds or even marine beds. The so-called marine diamonds are merely extensions of coastal alluvial deposits, running directly offshore. Alluvial deposits may be on the surface, or in gravels or under an " overburden " of sand up to 20 metres thick, or indeed on rough pebbly sea-beds. There is very good reason to believe that such diamonds originally came from pipes which were forced above ground level and were later weathered down into gravel-like deposits. Ultimately the deposits must have been washed into river-beds, towards coastal regions and into the sea.

Virtually all known diamonds before the 18th century came from India, from surface alluvial deposits around the small town of Golconda near Hyderabad in Andhra Pradesh. Most were small diamonds, though several quite famous large diamonds were also recovered. Some of them like the Koh-i-Noor, Hope, Orloff, Akbar Shah, Darya-i-Noor, Great Mogul, Nepal, Regent, etc have become historical legends. The Golconda mines virtually dried up in the mid-18th century.

Just as the Indian sources were drying up, a new source was discovered in Brazil in the state of Minas Gerais in 1725 (a priest who had become familiar with rough diamonds in India recognised these stones in the washings for gold in Brazil) and in Bahia in 1842. The latter contains an important variety of diamond called carbonado. It is black and opaque or just translucent with a metallic shine and, hence, called black diamond. Carbonado is extremely strong and is of great value for industrial uses, especially as a drilling tool and for shaping hard materials. The diamond deposits in Brazil occur both in low-lying river valleys and on high plateaus, but so far it appears that the original pipes have not been found.

The outlook of diamonds both as a gem and as an industrial material took a remarkable turn with the discovery of diamonds at Hopetown on the banks of the Orange River in South Africa in 1866. The first large-scale mine to be opened up was at the Bultfontein in 1869. In 1871, new finds at Dutoitspan led to a wild rush of prospectors and by the next year, five important diamond bearing pipes were uncovered in the Kimberley area. What distinguished South Africa from other areas is that seemingly inexhaustible supplies of diamonds were found locally in deep volcanic pipes.



The " Hope " diamond, 44·4 carats, deep sapphire-blue in colour, is haunted by legends of bringing ill luck to its owner — eleven violent deaths, tragedy in two royal houses. Now in private ownership in the US, the diamond which took its name from one of its earlier London owners, is believed to be part of the Tavernier Blue.

Jean Baptiste Tavernier, a French geographer who came to India in 1638 to buy precious stones, took back with him a huge blue diamond which he sold, along with 24 others, to Louis XIV in 1668. The Tavernier Blue was recut and made part of the French crown jewels. They were stolen in 1792 but the Tavernier was not among the few gems subsequently restored Later it reappeared, much reduced in size, as the Hope diamond.

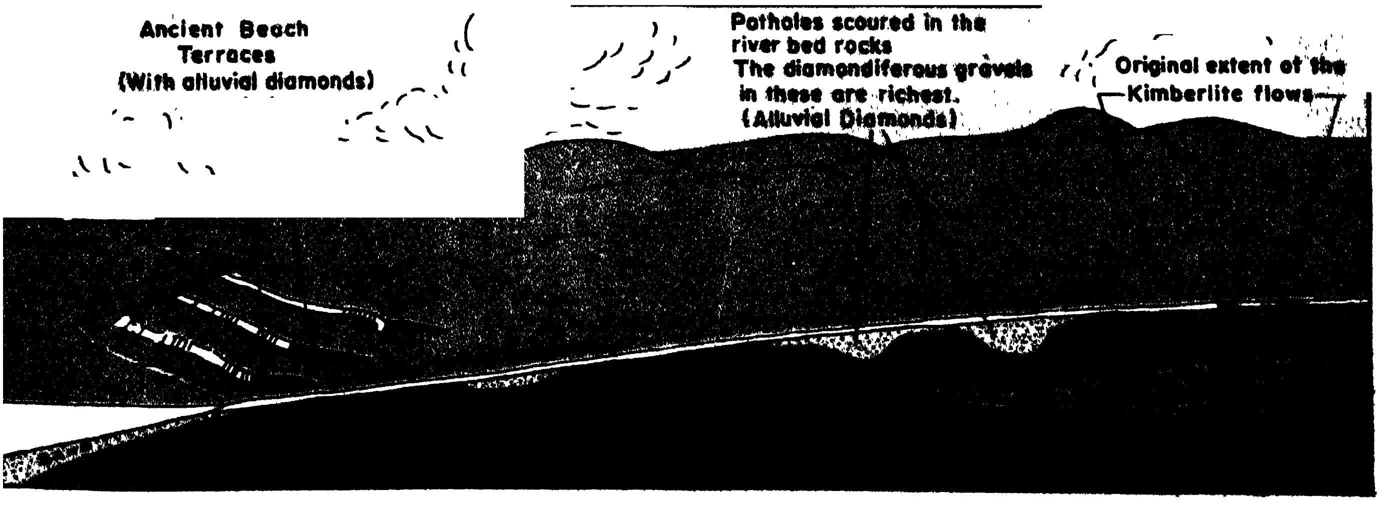
A more interesting discovery in the African continent was the location of rich deposits on the coast of Nawaqualand in South-West Africa and a little later on the coastline north of the Orange River in 1925. This region is the world's richest source for high-quality gemstones. Almost the whole output is of gem quality, unlike in even the best South African mines. In contrast, a diamondiferous area of about 100 million hectares stretching into neighbouring Angola which was discovered in the Belgian Congo in 1910, yields diamonds almost entirely of industrial quality (only two per cent suitable as gemstones). Other African sources include Ghana, Sierra Leone and Tanganyika. Diamond mines mostly in inhospitable and inaccessible areas are reported to have been discovered in the Soviet Union, but very little is known about the total production of these mines. However, Russia is now the only great industrial power completely independent of the African sources for the supply of industrial diamonds.

To be rated as a ' perfect ' gem, a diamond must be flawless. Impurities like ferric oxide, silica with traces of lime and magnesia together with gaseous inclusions like carbonic acid constitute the ' flaws ' (it is today standard practice to use the term ' inclusions ' in place of ' impurities '). The solid inclusions normally include garnet, diopside, olivine, pyrrhotite, chlorite, zircon, mica, etc. The presence of gaseous and other inclusions can reduce the density up to 3·10 gm per cc. The iron oxide is normally responsible for giving diamond the yellowish tinge.

Acids or alkalies do not act upon diamonds, nor does heat (except at temperatures above 800°C in oxygen or even in air, when it oxidises to carbon monoxide, or carbon dioxide). But if heated anaerobically to about 1900°C, it turns into graphite. Diamond can readily be oxidised and destroyed in a flux of sodium carbonate or of potassium nitrate.

However, it is in the uniqueness of its varied physical properties that diamond takes its place as the king of gems. Take, for instance, its form of crystallisation. The diamond crystallises as regular cube (only small diamonds from Brazil), octahedron, hexahedron

Fig. 1 Diagram of weathering erosion and transport of diamonds to gravels from host rock ' kimberlite '



Ancient Beach Terraces (With alluvial diamonds)
Potholes scoured in the river bed rocks
The diamondiferous gravels in these are richest.
(Alluvial Diamonds)
Original extent of the Kimberlite flows

tetrakishexahedron, rhombohedron and rhombdodecahedron — the forms belonging to the cubic system of crystallisation. Some morphological studies on Indian and South African diamonds indicate that many of the crystals belong to the tetragonal system of crystallisation. The structure of diamond consists of two similar Bravais lattices of carbon atoms of the face-centred cubic type, interpenetrating each other. Each atom in one of the lattices is linked to four atoms in the other lattice by valence bonds along the four trigonal axes of symmetry. Twinned crystals are not uncommon along the octahedral plane.

But the much talked-about hardness of diamond differs along (or across) different axes of the crystal.

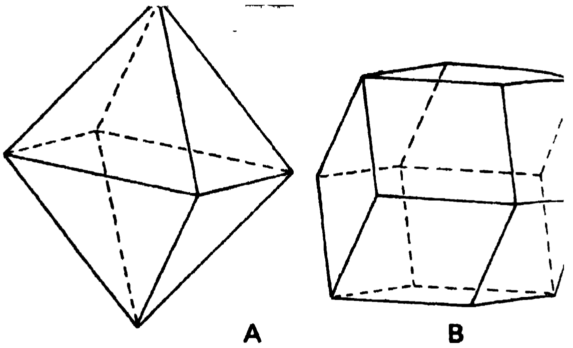


Fig. 2 The crystal planes of diamond

A: Octahedron
B: Dodecahedron (both common forms of diamond)
C: The hard (111) octahedral face
D: The soft (100) cubic face (making the 'table' cut)
E: Direction of cleavage on an octahedron

Processing of diamond ore

The extraction and recovery processes for the 'run of mine' ore differ from deposit to deposit and there is no fixed scientific method. In the 'treatment plant' the following processes are used so that a fixed quantity of the ore is treated daily for continuous recovery of diamonds: (1) primary crushing; (2) secondary crushing; (3) grinding; (4) screening for separation of different size fractions; (5) concentration; and (6) picking (manual-mechanical).

In case of 'run of mine' ore from kimberlites and older conglomerates, all the above processes have to be taken stage by stage, while in the case of unconsolidated gravels, stages (1), (2) and (3) can be skipped. In the case of kimberlites, the blue and yellow grounds (upper weathered parts of the volcanic pipes) are much softer than the hard kimberlite, and it becomes necessary to soak the 'run of mine' ore in water to remove the clayey slime; this may constitute up to 50 per cent of the total 'run of mine' ore. Also, in the case of certain soft layers at the bottom of diamondiferous conglomerates, such as the Banganapalle conglomerate in Andhra Pradesh, water-soaking in the initial stage may be necessary. The hard material is sent directly to crushers.

The 'run of mine' ore is brought to the treatment plant by dumpers and unloaded into the ore bin. The bigger pieces are crushed to enable them to pass through 250 mm size sieve and then fed to jaw crushers. The smaller-sized crushed material is sent to vibratory screens whereas the oversize material is passed through a roll crusher for secondary breaking. This, along with the undersized material from the vibratory screen, is taken by conveyor belts to finer size ore bins. The oversized material at this stage is sent to the secondary grinding mill or ball miller, where it is further reduced in size by steel balls. The crushing is done in stages to minimise the chances of breakage.

At the screening stage, the bigger size material is rejected first. The screening sizes may differ from plant to plant, and unless some diamond powder has to be recovered, sizes of the order of 1·25 to 1·75 mm are rejected. The screening provides materials of uniform size for feeding to the jigs (centrifuges).

The design of the jigs for concentration of the diamond-containing material also differs from deposit to deposit. Concentration is done by using the density difference between diamond (3·1 to 3·5 gm per cc) and gangue (valueless) material (around 2·8 gm per cc). The jigging is done using water as a medium, and concentrates of different sizes are obtained at every jig. This process considerably reduces the amount of material that must go to the 'pickers'.

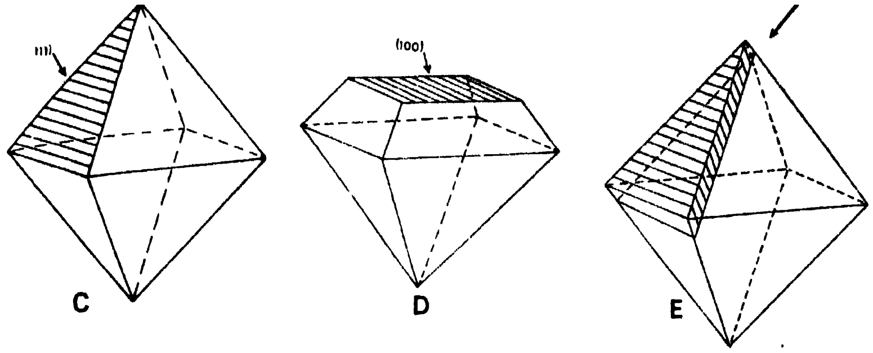
The pickers are experts who work by spreading the concentrates on cemented floors. Alternatively, the concentrates are carried over grease tables: diamonds stick to the grease and are removed. The efficiency of the grease table method arises from a curious property of diamond surfaces, namely, neither diamond nor grease is wetted by water so that the diamonds adhere to the grease. All other minerals are effectively coated (in the water) by a water layer and so slide off the sloping grease table. In modern plants, the diamonds are picked up from conveyor belts by using the technique of X-ray fluoroscopy which detects *all* diamonds present in the charge. There is no risk of any diamond being lost in this operation.

For the river and marine beach deposits containing diamonds, the constitution of the gravels, namely, the boulders, cobbles, pebbles, granules and the binding clay in which the diamonds are caught up, must be known for designing the treatment plant. Here the processes involved are washing, screening, jigging and diamond picking — all very similar to the treatment of primary kimberlitic ore or the secondary conglomerate ore. The 'run of mine' gravel is first dumped at the jarway over the 12·75 cm grizzley and later fed to the hopper bin. The conveyor belt then feeds the material to the mixer trommel. The very coarse materials (size greater than 2·5 cm) are sent to waste. Products smaller than this size are kept in the hopper and fed to vibrators where they are screened for different sizes. These are then sent separately to jigs for concentration. The concentrates thus obtained are sent to the yards for picking diamonds. (The above operations are carried out in a continuous circuit.)

The diamond roughs obtained from the treatment plants are examined and weighed; they are then classified into gems and industrials. The weight of diamond is expressed in carats, where 1 metric carat is equivalent to 200 mg. The diamonds are normally auctioned as roughs. The gem quality goes to the gem cutting industry, while the industrials are sold as per specifications to different factories. M. L. D.

Fig. 3 A cutter traces lines of cleavage on the surface of a rough diamond with pen and ink. After weeks of study, the stone is grooved to receive a mallet tap at the likeliest spot. A slight mistake may splinter the stone into pieces

How are the axes of a crystal defined? A crystal has a uniform symmetrical arrangement of atoms, that is, a unit atomic grouping which repeats itself regularly an extremely large number of times. It is the unit atomic grouping which determines the final shape of the crystal. The forces binding the atoms together can, however, act with different strengths in different directions. Consequently, in every natural crystal, the physical properties vary in different directions. The directions in a crystal are defined with respect to the crystal planes. The diamond crystal has eight "octahedral faces", each similar and triangular in shape. A number code system is used in crystallography to define faces and each face is given the code (111). The octahedron can be truncated to produce a square tabular plane. Such a plane is called a "cubic face" and



its code is (100) (see Fig. 2).

The octahedral (111) face is the " hardest " of all planes on a diamond, whereas the cubic (100) face is the " softest ". This differential hardness, accidentally discovered though, was the first secret of the diamond polisher's art and was known to the guilds of lapidaries in the medieval times, who held it as a trade secret within the family. One of the practical applications of this knowledge was that table-cuts were produced by lapidaries by grinding down the diamond octahedra. The principle used was *diamond-cut-diamond*, that is, the harder direction of diamond could abrade the softer. The table cut can be found in numerous pieces of medieval jewellery, for example, in rings and brooches. Later, the lapidaries began to attack the edges of the table cut, to produce shapes called the " brilliant cut " (see Fig. 5). This cut retained as much of the original octahedron as possible in the final gem.

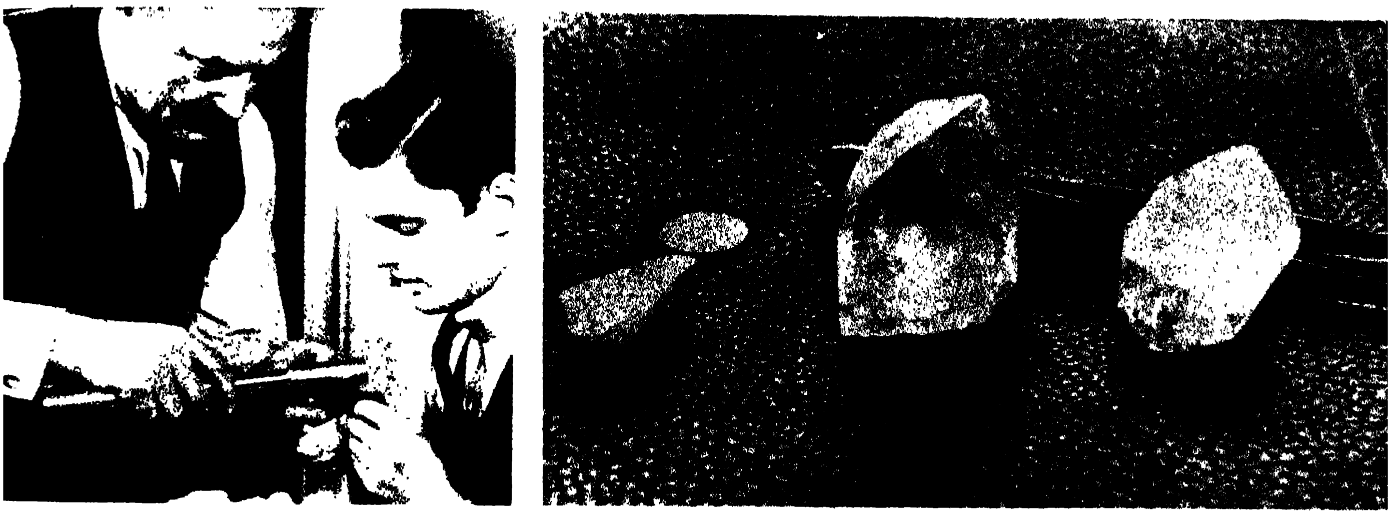
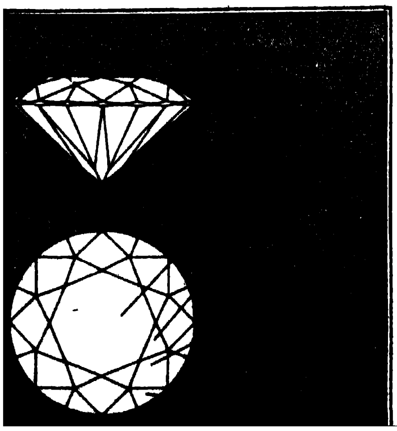


Fig. 4 Cutting the Jonker diamond. (Left) Lazare Kaplan's son Leo holds the dull-edged blade in the V-shaped groove made in the diamond and Kaplan prepares to deliver the fateful blow. (Right) The three pieces after cleaving was completed. After this, further divisions were made, but by sawing and not cleaving. Cleaving is done in the direction of the grain, but sawing is done against the grain and is immensely slow

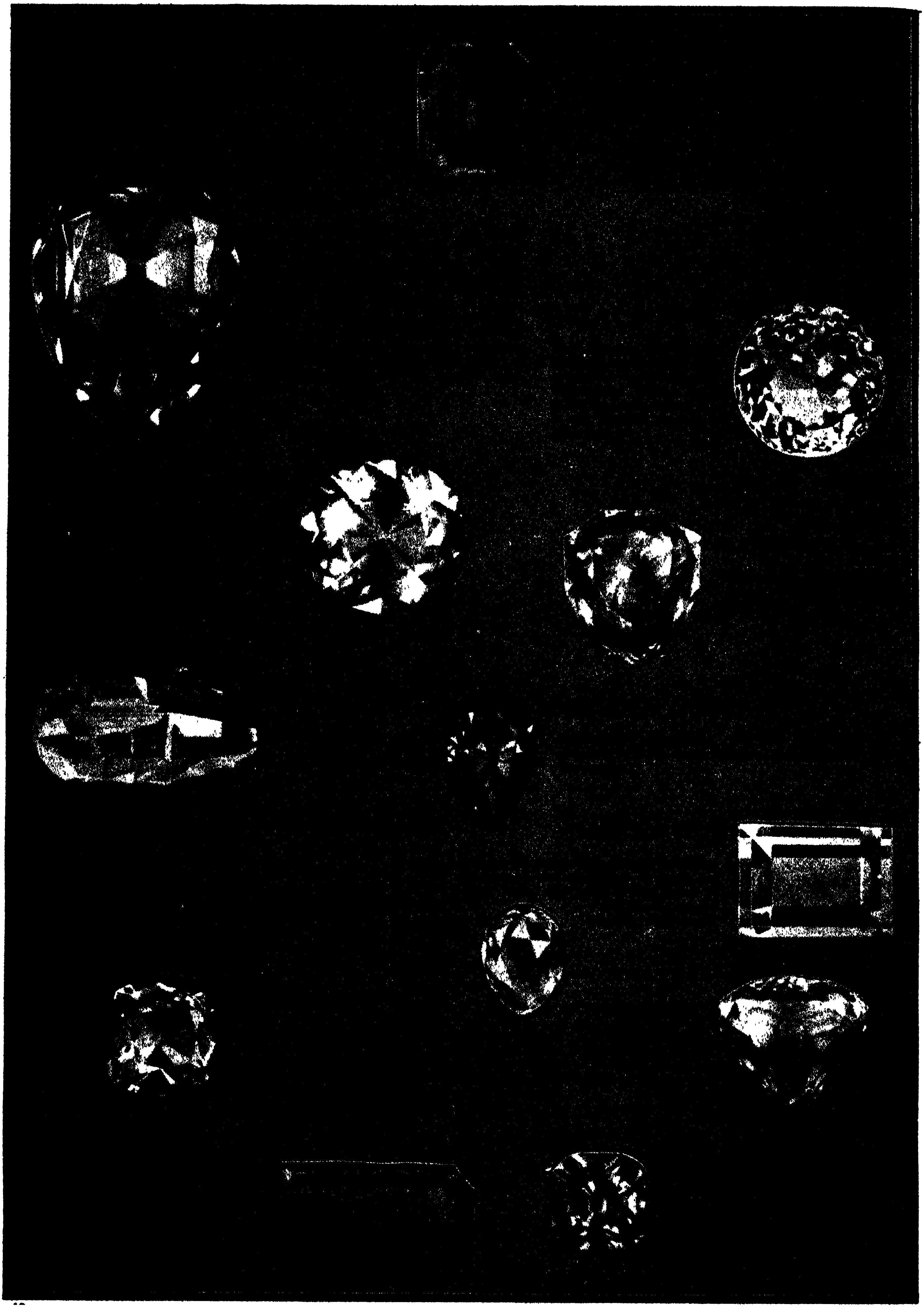
Fig. 5 Two views of a ' brilliant ' cut diamond showing the terms used for the various parts



Another curious property is that despite its great hardness, a diamond crystal cleaves with little difficulty. Diamond possesses both octahedral and cubic cleavages, the latter being relatively perfect and is taken advantage of in cutting the ' roughs ' into gems. Cleavage is actually a special property shown to varying degrees by different crystals. This is because, the atomic arrangement in crystals is such that in certain directions the binding forces are uniformly a good deal less than in other directions. These looser-bound planes are the cleavage planes. In diamonds, the binding forces perpendicular to the octahedral faces are the weakest. It is possible to scratch a nick called " kerf " in the edge of a diamond with another diamond. If a knife-blade is applied to the kerf in the direction of the arrow in Fig. 2 E in such a way that the blade is parallel to the (111) face, a smart blow on the blade propagates a shock through the crystal, which splits perfectly down a plane parallel to the (111) plane and the shaded piece separates off. Skill is paramount in directing the blow correctly or else the diamond may scatter. However, while cleavage is most useful to a diamond polisher, since he can bring an irregular shape to a shape nearer to what he ultimately needs, it is sometimes a disadvantage in the industrial applications; a specially-shaped diamond lathe-cutting tool or diamonds embedded in the heads of rock-drilling tools can split apart by cleavage.

A further mechanical property closely related to hardness is that diamond is least compressible and its compressibility is somewhere near a quarter that of steel. The table below gives the comparative compressibility figures for some gems and metals. If the volume elasticity or otherwise the resistance to compression of steel is $\frac{1}{68}$, that of quartz will be $\frac{1}{267}$ and that of diamond $\frac{1}{18}$. It is, perhaps, because of this high volume elasticity that the diamond ore can be crushed without in any way breaking the contained diamonds. This property also plays a big part in the most common industrial use of diamonds — for drilling and for cutting hard alloys and hard materials. Also for a hard material, the friction of diamond is surprisingly low — when rubbed

Substance	Compressibility (expressed as $\delta v \times 10^8$)
Diamond	18
Topaz	61
Emerald	75
Quartz	267
Glass	250
Copper	86
Steel	68



THE KOH-I-NOOR

Some say the Koh-i-noor is over 5,000 years old. However, the first authentic reference is found in the memoirs of Emperor Babur, founder of the Mughal dynasty in India. Babur wrote in 1526: "Bikermajit, a Hindu, who was Raja of Gwalior, had governed that country for upward of a hundred years (*sic*).

"In the battle in which Ibrahim was defeated, Bikermajit was sent to hell. When Humaiun arrived, Bikermajit's people attempted to escape, but were taken by the parties which Humaiun had placed upon the watch and taken into custody.

"Of their own free will, they presented to Humaiun a tribute consisting of a quantity of jewels and precious stones. Among these was one famous diamond, which had been acquired by Sultan Ala-ud-din. It was so valuable that a judge of diamonds valued it at half the daily expenses of the whole world."

The stone remained in the possession of the Mughal emperors till Nadir Shah's invasion in 1739. It is said, when Nadir Shah seized the Delhi Treasury, this stone wasn't among the treasure, but he soon learned that the defeated emperor, Mohammed, had concealed it in his turban. Invoking an old Hindu custom, Nadir Shah suddenly proposed to Mohammed an exchange of turbans, in token of reconciliation. When Nadir unfolded the turban in the secrecy of his tent, he hailed the sudden revelation of the sparkling gem with the exclamation "Koh-i-noor"!, which means "mountain of light".

According to the *National Geographic* magazine, which had researched and found the above account of the gem's history, the Koh-i-noor had changed hands several times after Nadir, and several of its owners had lost the gem in horrible torture. Somehow, the gem came back to India and after the Sikh rebellion and annexation of the Punjab, the Koh-i-noor passed to the East India Company with the stipulation that it be presented to the Queen of England, Victoria.

The illustration (top left) shows it in its supposed original state — some 800 carats, for many hundreds of years the largest diamond in man's possession. After its first cut, it weighed 191 carats; in 1862, it was carelessly recut (top right) to 108 carats.

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either against other surfaces or against itself. This property is made use of in the diamond stylus of record players.

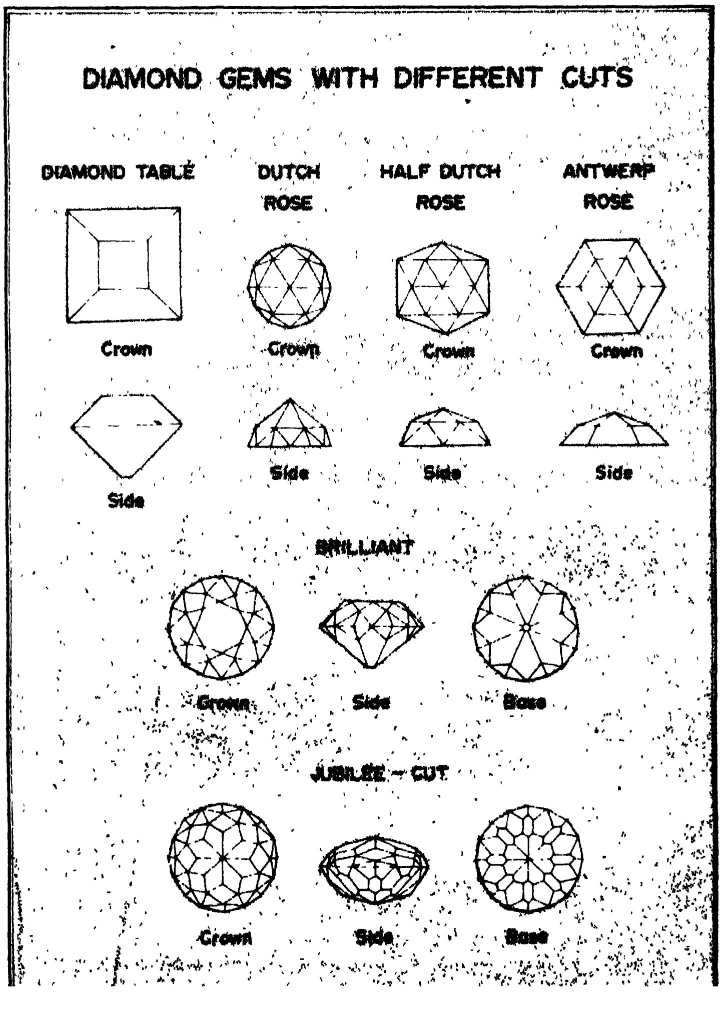
Optical properties

What causes the celebrated "fire" of the diamond? When light enters a solid or liquid from the air, it bends (or refracts) at the interface. This happens because the speed of light in the solid (or liquid) is less than that in air. The ratio of the speed of light in air to that in the solid (or liquid) is called the refractive index; for diamond, it is exceptionally high, namely 2·4, compared to 1·33 for water. And since the reflecting power of a transparent surface depends on the refractive index, diamond possesses a high reflecting capacity of 18 per cent — 4·5 times that of glass. This is why, light is strongly reflected by a well-polished diamond face

But, then, diamond also possesses a high dispersion. This means, it exhibits considerable difference in refraction for the different colours of the spectrum. The refractive index for red in diamond is 2·407 and for violet it is 2·465, the difference between the two values being 0·058. As a result, when white light enters a diamond at an angle, it emerges with brilliant colours. This gives rise to the 'fire', which can be seen clearly if the diamond is moved slightly or if it is illuminated by a flickering light, say, from a candle. Diamonds are normally cut with faces set at carefully chosen angles such that when light enters the crystal, it finds a face which *totally reflects it back*. Any beam striking the diamond face at an angle exceeding 24·5 degrees is totally reflected back, enhancing the "fire" of the diamond.

The birefringence (doubly refracting) property of diamonds had been studied by the late Prof. C. V. Raman (he spent a large share of his Nobel Prize money in the study of the peculiar optical characteristics of diamond) and his colleagues during 1944–47 and several other workers as well. Their research showed that the birefringence patterns exhibit bright parallel streaks attributable to oriented laminations inside the crystal — oriented parallel to octahedral or dodecahedral planes.

Unlike glass, diamond is transparent to X-rays. The colour and pattern of X-ray luminescence are less intense than those excited by ultraviolet rays. All diamonds show X-ray fluorescence, too, of blue and yellowish tinge, a little fainter compared to that of ultraviolet rays. Some diamonds show fluorescence in near ultraviolet (above 3,000 Å) while others respond to short ultraviolet rays (less than 3,000 Å). But only about 15 to 20 per cent of diamonds from the same source or deposit exhibit ultraviolet fluorescence. Thin diamonds, particularly the opaque varieties, reveal transmission up to 2,240 Å, the limit of the ultraviolet



Diamond Mining in India—Past and Present

An excellent account of the old diamond mines in South India is given in Tavernier's *Travels in India, vol. 2*. Tavernier, the French geographer, came to India several times in the 17th century and visited several producing mines in the Krishna river valley at Partiala in Krishna district and Kollur in Guntur district, where the diamonds were being recovered from the quaternary gravels formed by the Krishna river. He also visited the Ramallakota diamond mines in Kurnool district, where the diamond mines were located on the Banganapalle conglomerates. As per his account, about 40,000 workers were engaged in these mines (known as the 'Golkonda diamond mines' as the diamonds were then sold at Bhagyanagar — now Hyderabad — close to the famous Golkonda Fort). No account, however, is available about the production of individual mines. Jean Tavernier was, perhaps, unaware of the existence of diamond mining in that period at Panna in Bundelkhand district, at Sambalpur on the Mahanadi river and at Wairagarh in Chanda district. Apart from the abovementioned localities in Andhra Pradesh, there are several others, totalling more than 80, where old diamond mines in the form of either open cast workings or some underground shafts and levels are seen even today.

An interesting account of diamond mining near Banganapalle and Munimadugu in the former Madras Presidency is available in the *Memoirs, vol. 5*, of William King of the Geological Survey of India, who visited the mining activity there during 1871. According to him, the diamonds found there were smaller in size than the diamonds found in the gravels of the Krishna river.

The Deccan Mining Company attempted to operate some mines at Partiala during 1896—1904 and was successful in recovering 2,334 carats of diamonds. However, the glorious diamond mining activity that prevailed in the Golkonda region for a few centuries declined gradually and almost ceased by 1906. The important reasons were: (*i*) Competition from new mines discovered in Brazil and South Africa after 1728; (*ii*) the poor incidence of diamonds in the gravels and conglomerates, resulting in higher cost of production; (*iii*) exhaustion of the gravel material from the rivers and lack of facilities to locate new subsurface gravels; (*iv*) lack of proper facilities to crush the hard conglomerates to recover the diamonds cemented in them as only the softer layers in the conglomerates at the bottom were treated by the ancient miners; (*v*) the political instability during the 18th and 19th century in this region; and (*vi*) inability of the then mine owners to recognise the primary source of diamonds as kimberlite volcanic pipes.

Since 1967, the Geological Survey of India (GSI) has started exploratory work for diamonds in parts of Andhra Pradesh in different host rocks such as (*i*) volcanic pipe rocks, (*ii*) older conglomerates ('Banganappalle' in AP and 'Rewa' in Panna, MP), and (*iii*) river gravels (old). The volcanic pipe rocks, agglomerates resembling the kimberlites of South Africa, are the primary source of diamonds. Six such volcanic pipes have been located near Vajrakarur and Lattavaram in the Anantapur district of Andhra Pradesh and three in the Panna area in Madhya Pradesh. The pipe at Vajrakarur has so far yielded 25 diamonds altogether weighing more than 25 carats, the largest being a gem of 9·4 carats. From the economic point of view, the incidence of diamonds in this pipe is rather erratic and poor. There is, however, the possibility of discovering new kimberlite pipes hidden under soil cover in the vast stretch of the crystalline schists and granites of this region. A tract of about 6,000 sq km near Guntakal yields a few diamonds during the rainy season when the land is furrowed for cultivation. These finds support the view that hidden pipes may exist in this region below the soil cover. Modern geophysical methods using both airborne and ground surveys could be utilised to locate the deposits, if they exist. (All volcanic pipes need not be diamondiferous, since we know that out of about 100 pipes in South Africa, only about six contain economically extractable diamonds.)

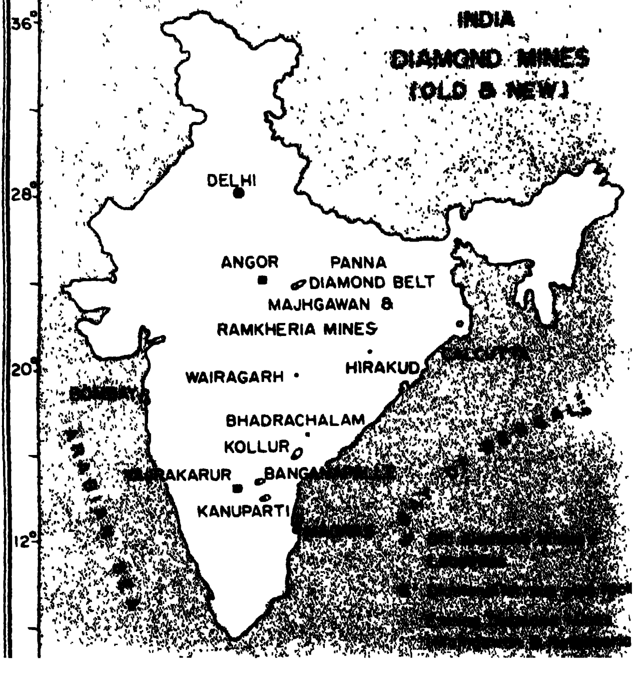
Andhra Pradesh also contains a tract of more than 3,000 sq km where the secondary source of diamonds, namely the Banganapalle conglomerates (about 600 to 800 million years old), are exposed in a series of hill ranges in the Kurnool district. These conglomerates derived their diamonds by the weathering and erosion of the kimberlitic pipes to the west of this area and then subsequent transport by the then-existing streams and rivers in the geological past. The numerous workings present here are restricted to the surface exposures of the conglomerates forming the plateau tops. Large tracts of the conglomerates under the cover of younger formations yet remain unexplored in the Cuddapah and Kurnool districts. Attempts at exploratory mining in Ramallakota area to recover diamonds from the 'Banganappalle conglomerate' by the National Mineral Development Corporation Ltd a few years ago were, however, suspended due to the poor incidence of diamonds as well as their small size (less than a carat).

The gravel beds, comparatively much younger in age (less than one million years old) belong to the Pleistocene and Holocene geological periods. These beds are formed as a result of the denudation of the diamondiferous conglomerates and kimberlites exposed in the catchment areas of the rivers and subsequent transport and deposition of this material in the river channels and banks. In Andhra Pradesh, the gravels found along the beds of the Krishna, Pennar and Tungabhadra rivers have been worked for recovery of diamonds. Some of the ancient mines were located in the gravels deposited in potholes (circular cavities) in limestones lying in the bed of the Tungabhadra river.

The ancient miners, however, confined their mining activities largely to the Krishna and Pennar river basins wherefrom they recovered large diamonds from abandoned channels, the gravels constituting the older terraces. These gravel beds, which occur within depths of 5 to 10 metres from the surface, form a potential source amenable to easy mining, treatment and recovery of the gems, without the need for crushing and consequent breaking of the diamonds. The programme of exploration in these unconsolidated host rocks is naturally based on a critical assessment of all available background information about the intensity of old diamond mines along the Krishna valley, depths of workings, amount of water available and the difficulties of open cast workings, etc.

The location of these workings studied with respect to the present channel of

Fig. 6 (Below) 47.9 carat "Vijay", the largest 'chance' find at Panna (by a rustic named Rasul Muhammad), is valued at about Rs. 3,00,000



the river gives an idea of the fluctuations of the stream in the past and aids in locating favourable sites, which can be confirmed by aerial and ground surveys. These areas are then taken up for drilling by ' hand augers '. Once the sub-surface gravel bed is picked up in certain holes, it is demarcated in all directions by a series of holes. An area of 44 sq km was covered by about 450 hand auger boreholes during the period between 1967 and 1972 and five virgin subsurface gravel patches were discovered in the vicinity of Partiala area. Bulk samples from two of these gravel patches yielded three diamonds weighing 4·2 carats, the biggest being a diamond of 3·25 carats.

Diamonds should occur at a minimum concentration of 5 to 6 carats per hundred tonnes of host rock with at least one ' chance ' find of a big diamond over 10 carats in a year if the mine is to be economical. If no chance finds are likely, the minimum caratage should be about ten per hundred tonnes and the majority of the diamonds should be of gem quality. The ratio of gems to industrials is also a factor to be considered in the economics of a mine. The host rocks of diamonds show a wide variation in diamond content, since there is a tendency of clustering of diamonds in certain portions of it. The recovery of diamonds from mines is, therefore, erratic and variable.

Another difficulty is that even after exposure of host rocks, there may not be any direct surface indication of the presence of diamonds. In such cases, the host rock is examined for the presence of paragenetic minerals (minerals formed with the diamond) which act as ' path-finders ' for diamonds. These minerals include picroilmenite, pyrope garnet and chromediopside. In the case of hidden bodies, indirect methods like geophysical and geochemical surveys and the study of paragenetic minerals in stream sediments are resorted to during initial stages of prospecting. Once a kimberlite, a conglomerate or a gravel bed is located, further exploration consists of excavation of the rock for bulk treatment for the recovery of diamonds.

The sporadic attempts at mining in the Panna area in Madhya Pradesh around Majhgawan was the only source of Indian diamonds till 1969. Later, prospecting and systematic work in the Majhgawan volcanic pipe, the Rewa conglomerates and the gravels of Bagen river at Ramkheria led to the opening of systematic mining, treatment of material and recovery of diamonds, thereby establishing the only diamond producing mines in India today. Two more pipes namely the Angor and Hinota were discovered and proved to be diamondiferous. But the incidence of diamonds being poor, no diamond mines could be opened at these sites. The discovery of a kimberlite dyke at Chelima in Andhra Pradesh has also been reported. The exploration work is still in progress in the neighbourhood areas. M.L.D.

transparent type. The infrared absorption spectra of some diamonds, the non-luminescent type, are found to be completely non-absorbing in the frequency range 770 cm^{-1} to 1,400 cm^{-1}. The luminescent types show a band in this region with a number of absorption maxima.

There are a few diamonds, mostly the synthetic ones, which are highly transparent in the infrared and find application in defence in what are called infrared image converters.

When it comes to colour, colourless diamonds (sometimes known as " blue white ") are supposed to make the best gems, though coloured stones, usually pale yellow or smoky brown, are more commonly found. In fact, some beautifully coloured diamonds — known as " fancy stones " — are priced very highly; the Hope diamond is deep sapphire blue, the still costlier Dresden is green and the Tiffany diamond is a rich orange-yellow.

Yet, colour can be induced in colourless diamonds *artificially* by irradiation. By bombarding with neutrons from an atomic reactor or by charged particles from a cyclotron, diamonds of commercially undesirable yellowish tint can be turned green, and stones of brown or golden-yellow hue can be produced from these by subsequent careful heating. By electron bombardment, stones of distinctly blue or bluish-green colour can be obtained. The irradiation causes displacement of atoms in the diamond crystal, leaving gaps in its structure which thus affect the absorption of light. The colour of a diamond can also be changed to green by exposure to radium or its salts.

Fig 7 Every known gem has its own refractive index The refractometer shown above identifies the gem by the light it bends — by means of mirrors, lenses and a graduated scale. Another clue is the stone's specific gravity, or the stone's weight compared with that of an equal volume of water (measured with the balance seen in the background)

Thermal properties

Just as good conductors of electricity are also good conductors of heat, since both heat and electricity in a substance are conducted by means of free electrons, good insulators such as glass or porcelain are also poor conductors of heat. Yet, though diamonds (apart from one or two exceptionally rare blue diamonds) are very good electric insulators, surprisingly, they conduct heat extraordinarily well. The reason:

Deciphering diamonds from duds

A number of stones and substances may look like a diamond, but a trained person can easily distinguish a diamond from these substances due to its unique characteristics. The following properties of diamond are generally used in identification: *specific gravity* = 3·2, *Hardness* = 10 *on Moh's scale*, and *refractive index* = 2·417. Besides, a strong dispersion of light and adamantine lustre suggests diamond.

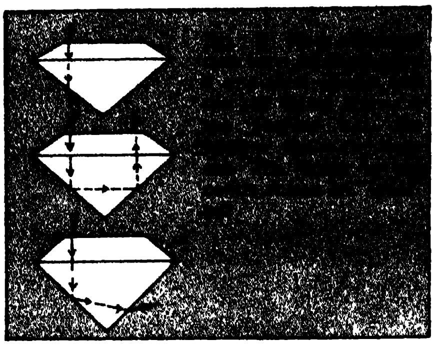
Colourless quartz looks like diamond but lacks the fire. White zircon, synthetic white sapphires and synthetic white spinel are often used as imitation diamonds. They are not easy to detect when small brilliant cut and baguette cut stones are used in imitation jewellery. Strontium titanate, sold as Fabulate and Diagem, is another diamond simulant. It has an unusual degree of fire but low hardness. Another substance is yttrium aluminium garnet (YAG) sold in the name of Diamonair and Cirolite, but it has less fire than diamond. Lithium niobite sold as Linobite has more fire than diamond but is soft.

If any doubling or rear-edge facets are seen, diamond can clearly be ruled out; the stone should either be zircon or lithium niobite. Glass stones and strontium titanate usually give a moulded look to the facet edges as compared to the sharp edges in diamonds. Strontium stones and synthetic sapphires show more fire than diamond, whereas synthetic spinel shows less fire. And the reflections from the table facet of diamond are sharp and undistorted but in other stones the images are slightly blurred. K.A.N.

Fig. 8 A handful of famous diamonds (shown on p 40)? Believe it or not, all are perfect imitations made of quartz, owned by Giafomo Longo of Milan, Italy

the heat is not conducted in diamonds by free electrons but by types of crystal vibrations called phonons — a sort of wave propagating through the crystal.

This ability of diamonds to conduct heat is used by professionals as a test to distinguish genuine diamonds from fakes. The method is very simple. The object to be tested is kept on a table for sometime to attain room temperature. It is then picked up with a handkerchief and placed on the top of the tongue. The diamond feels cold like a metal because it conducts away heat. The fakes — either zircon, quartz or a specially dense kind of glass called "paste" — being poor thermal conductors remain warm to the feel of the tongue.



An even more remarkable thermal property of diamond is its exceptionally low coefficient of expansion. All bodies expand when heated, yet amongst the lowest expansion of any material known to science is that of diamond — even less than the unusually low-expanding metal invar. The two thermal properties — good heat conductivity and low expansion — make diamond an ideal material for machinery uses. Diamond tools — used mainly as cutters and grinders — do so much work that they get very hot; their excellent conductivity ensures that the heat is dissipated away — to their metal matrix holders. And the low expansion property ensures that when used as a grinder or an abrasive, the diamonds hardly dilate with the heat they retain.

Diamond cutting and polishing in India

The cutting and polishing of diamonds in India is mainly an export-oriented and labour-intensive cottage industry providing employment to more than a lakh of artisans and craftsmen. The industry is now mainly concentrated in the west coast of India at places such as Bhavnagar, Surat, Navsari, Bombay and in some parts of Kerala. The lapidaries in these places produce single cuts, brilliant cuts, baguette and marquise and also process other fancy shapes.

The industry still depends on dexterous and experienced hands and not machines (except a few firms in Bombay which have imported diamond-cutting machines). The cutting and polishing are carried out by means of simple tools. The imported rough diamonds (50 to 60 per cent of the roughs are imported from UK and the remaining from various sources such as the Antwerp open market) are first assorted quality-wise, size-wise and shape-wise. The diamond is then cleaved by means of a thin disc of relatively soft metal, whose edge is slightly indented. A single piece is slit into as many pieces as necessary, removing as many natural flaws as possible. The cleaved diamond is then cemented to a wooden stick for rough shaping against an emery or carborundum wheel. Having charged the lap with appropriate abrasives, the lapidiary first grinds the table facets. The other facets are then ground to their correct proportion and angles according to the design of the required cut. After the cutting is complete, the diamond is polished by means of diamond powder. Here master craftsmanship plays its part by correcting even a slight irregularity in the proportions left by the cutter. Polish imparts a brilliant finish and the diamond is ready for marketing after assortment.

Antwerp in Belgium is, however, the world's leader in cut and polished diamonds, the turnover approaching more than a billion dollars. The United States takes about 35 per cent of Belgium's total diamond exports. Next comes Israel, followed by India. Though Indian workers are said to far excel their European counterparts, especially in their skill in cutting the diamond, modern technology has enabled Belgium and Israel to outpace the Indian cutting industry in finish and output. For the smaller size diamonds we cut, use of semi-automatic dops would give a much larger output. For brutting, the Indian industry still uses centreless chuck lathes. However, for very large production, the Israelis and the Belgians have now adopted double-spindle lathes. For faster and rapid abrasion it is essential to evolve polishing benches with improved scaife cutting technology. Also for better and faster polishing of diamonds, the diamond powder collected during processing of rough diamonds has to be purified.

The rough diamonds polished in India at present are almost exclusively small in size and of a category known in the industry as "makeables". The Indian industry has gradually to shift and diversify from "makeables" to "sawables" for varied production and wider employment.

There is also need for better grading of diamonds. The value of a diamond is determined by four main characteristics, namely, its carat weight, cut, clarity and colour. Carat weight is determined by means of an electric balance accurately up to two places of decimals. Generally, the style of the cut and the proportions and symmetry of cut are not, at present, measured in the diamond business in India. However, a trained eye can easily detect the difference between an excellently cut diamond and a very badly cut one. (Correct proportions on a brilliant cut would give maximum brilliance; see Fig. 9.) When it comes to clarity, the standard technique used for detecting inclusions is to view the diamond in the morning in north light (light entering the room via a window facing north) by a 10 × magnification hand-held lens. Every diamond of size greater than 0·03 carats is graded in India for clarity.

Colour grading is also done under north light with the diamond placed on a white background. The diamond under test is compared with a set of reference diamonds. The colours are graded as blue white, fine white, white, commercial white, light colour, etc.

The Indian diamond trade exported Rs. 231·05 crores worth of cut and polished diamonds in 1976-77. But it is regrettable that few facilities exist in the country for the testing and grading of diamonds using modern equipment and accessories. The only recognised laboratories are the Gem Testing Laboratory at Jaipur of the Gem and Jewellery Export Promotion Council and the laboratories of the Gemmological Institute of India at Bombay created by the Precious Stones Importers and Exporters' Association.

K.A.N.

Fig 10 Two faces of diamond cutting in India. (Left) A cutter at work with archaic hand-controlled tools. (Right) Modern technology has come in the shape of 'dops' that hold the diamond against the polishing wheel which is coated with diamond powder

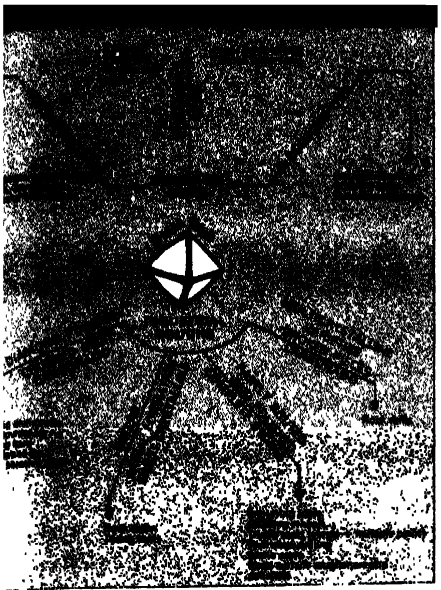


Fig. 11 Chart showing the different uses of diamond

Industrial uses

Notwithstanding its renown as a gem, the industrial uses of diamond are so vast and varied that the diamond is now called the " monarch " of modern industry. And the most important of its properties made use of in industry is its hardness.

It is difficult to make an absolute measurement of the hardness, but it has been indicated that the hardness of diamond is between 90 and 180 times that of corundum. Diamond, therefore, can cut diamond itself. Bort and carbonado diamonds are particularly useful in industrial applications since the cleavage property of their individual crystals is masked by their crypto-crystalline structure, composed essentially of minute interlocking crystals of diamond, which makes them extremely hard without the tendency to split under a heavy blow.

Diamond tools are used in shaping the internal combustion and diesel engines. Bearings, particularly the bronze bearings in connected rods, are bored by diamond drills for uniform dimensional accuracy and high finish. The grinding wheel used in grinding components to finished sizes are diamond-trued; about 70 per cent of the supply of bort goes into grinding wheels. The commutators of starter motors and dynamos are machined with diamond-tipped tools. Diamond tools are also used in aircraft production, machine tool industries and widely in glass and optical industries. Diamond saws find an important place in cutting glass. They are also used in free hand engraving in glass, cutting optical glass for lens and prism-making and in bevelling and edge grinding of mirrors and table glass.

Diamond dies use industrial stones for drawing wire of a constant diameter, normally less than one millimetre. Platinum alloy wire 0·00066 cm in diameter and tungsten wire 0·0007 cm in diameter used in lamps, radio tubes and electronic components are drawn through diamond dies. The diamond dies used for wire drawing must be free from inclusions and flaws.

Then, a large quantity of the industrial diamonds (bort and carbonado) are used as drilling bits. The diamond should be large enough to grind the grains of the rock formations and still allow sufficient space between the rock and the matrix for clearance. Diamond bits are also extensively used for drilling concrete and other man-made material, holes for pipes, cables, etc.

Diamond powder is produced not only from natural diamonds but from synthetic ones, too. It is mainly used as an abrasive for (*i*) sawing, rough polishing and fine polishing of gems and shaped tools; (*ii*) polishing tips of tungsten carbide tools; (*iii*) piercing, reboring and polishing of wire drawing dies; (*iv*) sizing and polishing of gramophone needles; and (*v*) lapping and polishing of hardened steel, gauges, metallographic specimens for microscopic studies, etc. The diamond powder is used in hones and hand laps in resin-bonded abrasive wheels. Electro-deposited tools are used in dentistry and electro-deposited grinding wheels, as cutting saws in ceramic, refractory, tiles and the glass industry.

To be honest, if we were to tabulate all the industrial uses of diamond, the list would easily run into tens of pages. And yet there are several other potential uses in various industries awaiting development.

SYNTHETIC DIAMONDS

[illegible] 1797, when diamond was first shown to be a form of carbon. In the decades that followed, scientists in many countries tried — and failed — to convert carbon, an abundant and inexpensive substance, into diamond.

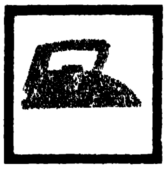
The work of Prof. P. W. Bridgman, an American physicist, on the production of very high pressure and its effects on various substances gave a special impetus to the production of synthetic substances. In 1951, the General Electric Company of America launched a major investigation into the effects of high temperatures and high pressures at its Research and Development Center in Schenectady, New York. And in 1955, came the news of the creation of tiny diamond crystals by a reproducible laboratory process. The transformation of graphite into diamond was accomplished by the action of a molten metal catalyst such as nickel and the simultaneous application of pressures of over 100,000 atmospheres (obtained by means of a giant hydraulic press) and temperatures of more than 2,500°C, in a very small pressure chamber; the process had to be repeated several times. The largest synthetic diamond produced was only 1·2 mm in length and about a thousandth of a carat in weight.

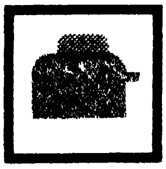
Most of the small synthetic diamonds are categorised as industrials. Man-made diamonds — because of their controlled properties tailored for specific industrial uses — have proved superior to natural diamond for many applications, and their production has been gradually stepped up during the past two decades. It is now estimated that [illegible] and West Germany. [illegible] Physical Laboratory, Delhi, has been making attempts to produce synthetic diamonds.

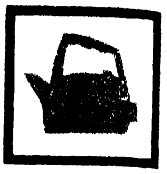
The artificial production of gem diamonds — particularly of bigger size — is still more difficult. However, in 1970, the General Electric Company scientists announced that they had created gem diamonds in the laboratory, again subjecting graphite to [illegible] pressures and temperatures in a special apparatus. The process they used started with a seed crystal. This seed crystal, along with a metal catalyst and man-made diamond powder, was then subjected to high pressures and temperatures in a special press. The high temperatures melted the metal catalyst and dissolved the diamond powder. (The end of the chamber containing the seed crystal is kept cool enough so that the " seed " will not dissolve.) By carefully controlling the pressures and temperatures involved, the carbon atoms from the diamond powder were made to migrate through the molten catalyst and redeposit themselves upon the seed crystal, forming a large diamond. The process was long and complicated and took several days. The GEC scientists have also learnt to control the colour and clarity of the gem diamonds, as well as their ability to conduct heat and electricity by controlling the impurities in the growing crystal. However, synthesised, carat-sized gems are many times more expensive than mined diamonds.

M. L. D.

Mr. Deshpande, a senior geologist with the Geological Survey of India, is Officer-in-charge of the Map Division, Central Region, at Nagpur. He has done exploratory work for diamonds in Andhra Pradesh, tin in MP and base metals in Karnataka.







HOW GOOD ARE OUR ELECTRICAL APPLIANCES?

P. J. JOGLEKAR
S. T. PATIL

Of the various types of heating appliances, a room-heater is the simplest. The heat radiated by the heating element heats the surroundings. If there are preferred directions for the heat to be radiated, suitable reflectors can be used. The heating element is mounted such that no shock hazard is likely.

The next in complexity is the electric stove. Fairly simple in construction, it uses an open-type heater. Since it is used for cooking food, some care is necessary in its design to prevent the possibility of a shock. The toaster, on the other hand, is a handy appliance which serves a specific purpose. Since bread slices are inserted inside, precautions become necessary here also. Hot plates and irons provide various controls and are somewhat more complicated. Appliances used for heating water form a separate class. They need extra precaution.

The heart of a heating-type domestic electric appliance is a resistance wire, known as a heater element. It is usually made of an alloy of nickel and chromium, or iron and chromium, etc. The composition depends on the temperature it has to develop — without itself softening or melting. It also depends on the electric supply voltage on which it works. The most popular and commonly used wire is nickel-chromium, called " Nichrome ".

The Nichrome wire is available either as a normal round wire or as a flat ribbon. The normal percentages of nickel and chromium are 80/20 or 60/15 (the rest is mostly iron). The usual relationship between temperature and composition is: Nichrome 80/20, 1,200°C and Nichrome 60/15, 1,150°C.

The parts on which the heater element is supported or fixed must also withstand this high temperature and the supply voltage. Ceramic refractory materials like China clay, asbestos, mica and manganese-dioxide are the most commonly used materials. Which of these materials is used will depend on the type of appliance and how the heat generated is to be transferred efficiently.

The heating element is normally sealed within an insulating material which has a good capacity to conduct the heat from the element to the surface of the sealed unit. At the same time, the insulation has to keep the surface free from any leakage current or part of the supply voltage appearing thereon. This is vital for safety against hazards of electric shocks.

In hot plates and cooking ranges, the heater element is sealed inside metal discs, which are filled with insulating materials like mica, or asbestos sheets or powder. A further improvement is to put the heating element in a copper or brass tube and fill it with manganese-dioxide powder. This is a precision job and has to be done with automatic machines to ensure that the heater wire has maximum electrical resistance to the outer tube, but least thermal resistance for efficient heat transfer to the outer tube. This tube is then bent in a spiral shape to suit the size of the hot plate required. The heat transfer in this type of hot plates is far more efficient than in solid plates with embedded heater coils.

Heat transfer

This brings us to the problem of transfer of heat from the heating element to the surface of the appliance. Depending on the type of appliance, this heat is transferred either by radiation through air (as in ovens, toasters, room-heaters, grills, etc) or by conduction through a material with high electrical insulation but good thermal conductivity or capacity to conduct heat (as in electric irons, hot plates, water heaters, etc and, as mentioned earlier, refractory grade ceramics, mica sheets, asbestos papers or manganese-dioxide are used). While this transfer of heat should be as efficient as possible, one has also to ensure that the heat is not wasted by conduction or radiation in unwanted directions and ways. Radiation in undesired directions can be avoided by using heat reflectors as in room-heaters. Wastage of heat by conduction occurs in several ways — through the hardware fixtures and electrical connections. The heat damages the surface finish of the metallic objects, that is, electroplating, painting, etc. It also burns the insulation of the electrical wires connected to the heater elements. To minimise this damage, ceramic beads should be used on the electrical wires near the heater connections. Also, the wires used within the appliance of the heating type should belong to insulation class of B or H as far as possible. This precaution will increase the life of the wires, which are subject to heat.

Temperature control

To use an appliance efficiently, it is essential to control the heating. The control should be automatic as well as fool-proof. Heat control in an electrical appliance is

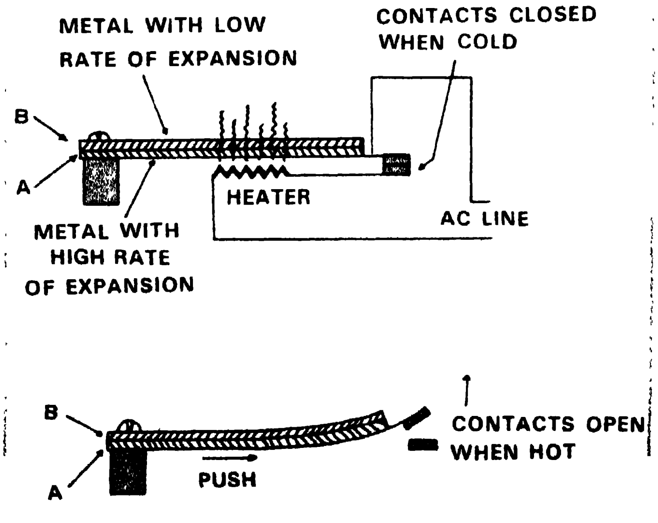

METAL WITH LOW RATE OF EXPANSION
CONTACTS CLOSED WHEN COLD
B
A
HEATER
AC LINE
METAL WITH HIGH RATE OF EXPANSION
B
A
PUSH
CONTACTS OPEN WHEN HOT

Fig. 1 A strip of tw metals with dissimilar co efficients of linear expan sion will bend when it heated. The deflection proportional to the tempera ture to which the bimeta is heated. The resistance o the bimetal is such tha when a current passe through it, it gets heate and deflects to break th circuit at point B. Poir B can be adjusted to ge a temperature control. Whe the heating is stopped, th bimetal gets straight an makes the connectio again

best achieved by controlling the voltage and current. This is easier than controlling the heat generated. All temperature controls, therefore, either regulate the voltage and current or the time during which the electrical energy gets converted into heat in the resistance wire.

In appliances like hot plates, ovens, etc the basic component for the control of voltage/current is a switch with four positions. This is usually achieved by using one element, or two separate heating elements, connected either in series or parallel. Thus, this switch enables one OFF and three ON positions. In the low heat (ON) position, the two elements are connected in series to the mains supply; in the medium heat position, only one element is used and in the maximum heat position, the switch connects both elements in parallel.

It is possible to adjust the appliance so that a particular temperature is not exceeded. The device which senses the temperature and actuates the electrical supply is known as a thermostat. It is based on the bending of a bimetallic strip when heated (see Fig. 1). The thermostat will switch off the electrical supply at a set temperature and will again resume it when the temperature drops by a few degrees. There is a small range of temperature around the set value, within which the thermostat will regulate the temperature. This range is a measure of the thermostat's sensitivity; the smaller this range, the more sensitive the appliance.

Thermostats are used in appliances like storage type water heaters and other appliances of better quality such as ovens, electric irons and washing machines with internal heating. The bimetal strip protects the electric circuits of the appliances. When a maximum rated current of an appliance is exceeded, the bimetal temperature reaches a level at which the supply is cut off. Such a device is called a 'thermal cut-out'. (The principle of thermostat is also used in appliances like toasters. But there the bimetal only switches off the current; it does not switch it on, which is done manually.)

Voltage and current transient characteristics

Such protection is necessary because of the voltage and current transients — very sharp rises in voltage or current over a very short period of time. Transients are likely to occur, whenever there is a sudden change in load conditions in the appliance or the neighbouring electrical networks. When a high voltage circuit switches off a large current, there is a very high rise in voltage not only in the high-voltage network but also in the low-voltage distribution systems. This can give rise to a transient voltage in domestic supplies. Similarly, when an appliance is switched on full load, there is a sudden large inrush of current, which can be as high as 10 times the normal full load current (see Science Today, September 1977, p. 45). This is because of the fact that the resistance of a heater wire in cold condition is quite low compared to its resistance in hot condition. Not only the appliance or the heater element but also components like switches, connectors, wires, indicator lamps, etc should be designed to withstand such voltage and current transients. The voltage transient characteristics can be improved by the use of proper insulating materials. If the insulation level is marginal, then the voltage transients will affect the appliance.

To improve the current transient characteristics, the conductors must have an adequate rating. This avoids overheating of these parts even for short periods. Otherwise, the insulation of overheated parts will deteriorate and cause leakages, leading ultimately to a total breakdown of the insulation. In such an event, a short-circuit will occur or the full voltage will appear on the body of the appliance.

The electric stove

Though it is one of the simplest of appliances, the electric stove or oven is perhaps also one of the most hazardous. In fact, it should be banned from the market unless strict quality control is maintained. The heating element in an oven is a filament made from coiled Nichrome wire; it is accommodated in the grooves of a China clay plate (sometimes called brick). The ovens come in various designs in a wide price range. Several unauthorised manufacturers make it in its crudest form (Fig. 2) and there is always a possibility of a shock.

The heating element in an ordinary stove is just connected across the supply terminals by a two-pin connector. The element is embedded in a groove; normally it does not come in contact with the vessel kept on top. However, due to spillage of water or other liquid, the element gets burnt at some point or other. As it is possible to reconnect the broken filament, one may not find it necessary to throw it away. But in the process, the element gets loose and tends to bulge out of the groove, giving a shock. The element is then generally pushed back into the groove. With further breaking and repair, the filament gets shorter and the wattage increases. (This may appear surprising at first. But since the length of the coil is reduced, its resistance is also reduced proportionately. Thus the element draws more current and consumes more power.) And if the connecting wires from the terminals to the heater element do not have the capacity to carry the excess current, they get overheated. Consequently, the insulation, or the wire itself, gets burnt. This causes a fault, which can be set right by replacing the connecting wires. What is worse is the possibility of one of the leads touching the body of the appliance, giving a shock. To avoid these hazards, the body of the stove should be earthed (see Science Today, September 1977, p. 45), and a hinged metal stand may be used to keep the vessels. The ISI specification lays down the various precautions.

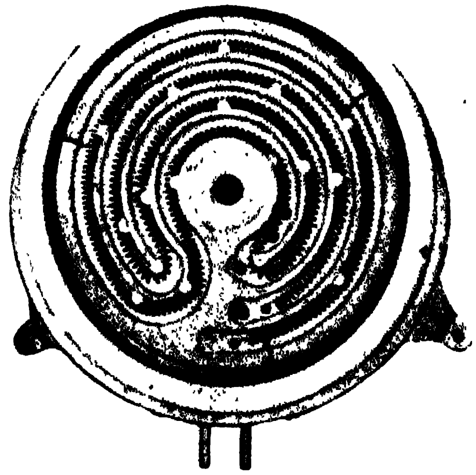


Fig. 2 The electric stove. This is a crude design. The heating element is exposed, and a two-pin plug is used

Toaster

The toaster is a simple and efficient appliance, specifically for toasting sliced bread. Electric cooker grills can also make toasts, but they take a long time to warm up. For toasting one or two slices, toasters are quicker than the grills; for large quantities, say in excess of six, a grill is faster. Toasters come in two designs — the ordinary type in which the slice has to be taken out when done, and the automatic pop-up type where the toasted slice is thrown up automatically. The automatic type provides browning control, to give from pale to dark brown coloured toast. It also provides consistency in browning. However, if the browning control is based on time, the first slice would be less brown. And if you use a slice so thick that it needs to be pushed in or so thin that it curls when toasting, the pop-up mechanism may get jammed and the toast may catch fire. This can further damage the insulation inside the toaster and affect its safety.

Since the pop-up toaster costs about thrice as much as an ordinary one, the ordinary type is more commonly used. But here there is a possibility of the toast burning if one is not attentive.

The mechanism provided at the bottom to remove crumbs from the collecting tray must be operated after disconnecting the mains. In some of the imported models, there is an interlocking mechanism such that one cannot clean without disconnecting. The crumbs create some peculiar problems; they usually attract cockroaches, and when the toaster is switched on, the cockroaches pop out before the toast, and occasionally, even after. One should never insert any metallic object like a spoon or a knife while the toaster is switched on.

In our survey, we did not come across a single toaster with ISI marking, though there is an ISI specification for the toaster. Most of the tests prescribed are general tests for safety requirement, with some minor specifications pertaining specially to the toaster. The only special test is the toasting test (see box on p. 49).

Hot plate

The heating elements in a hot plate are either embedded within a cast body (solid element) or enclosed within a tubular metallic sheath (sheathed elements). Since the element is thus enclosed, the shock hazard is greatly reduced. But the surface of the hot plate is exposed to the cooking ingredients through spillage. It is also likely to be subjected to temperature stress when cold water spills over it.

According to ISI standards, the thermal efficiency of the hot plate is expected to be at least 80 per cent. This is measured by finding out the electrical energy consumed to heat a specified quantity of water through a specified temperature difference under specified conditions.

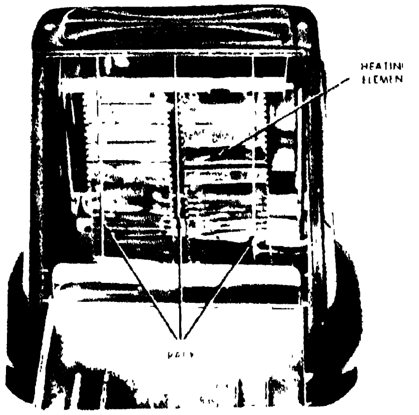
Electric iron

Electric irons are of two types: (1) automatic and (2) non-automatic. An automatic iron is fitted with a thermostat whose setting may be adjusted manually to alter the sole-plate temperature to suit different types of fabrics (see table below). Non-automatic irons just have a heating element and no control to adjust or limit the temperature.

FABRIC	TEMPERATURE (°C)
Nylon	70 to 90
Rayon	100 to 120
Silk	130 to 150
Wool	160 to 180
Cotton	200 to 220
Linen	230 to 260

The ISI lists two more types of irons: (1) iron with a self-resetting thermal cut-out, and (2) iron with a non-self resetting thermal cut-out. However, a survey showed that these two types are not available in the market. Automatic irons are available for Rs. 135, whereas the simple non-automatic types are available for Rs. 40. The manufacturers apparently feel that the iron should be either very cheap or should provide the sophisticated controls.

The ISI specifications stipulate that for irons without thermostat the temperature of the sole-plate is maintained at 250°C ± 10°C by switching the supply ON and OFF. In the non-automatic type, this is done manually. One has to be, therefore, careful about the temperature, or the garment may get burnt. None of the irons available in the market had ISI marks. The automatic types sell under established brand names, while the ordinary types are available under various labels. On enquiry, it was found that this is a household industry, and one could buy in a lot and fix any label. Quality control, obviously, is a far cry.



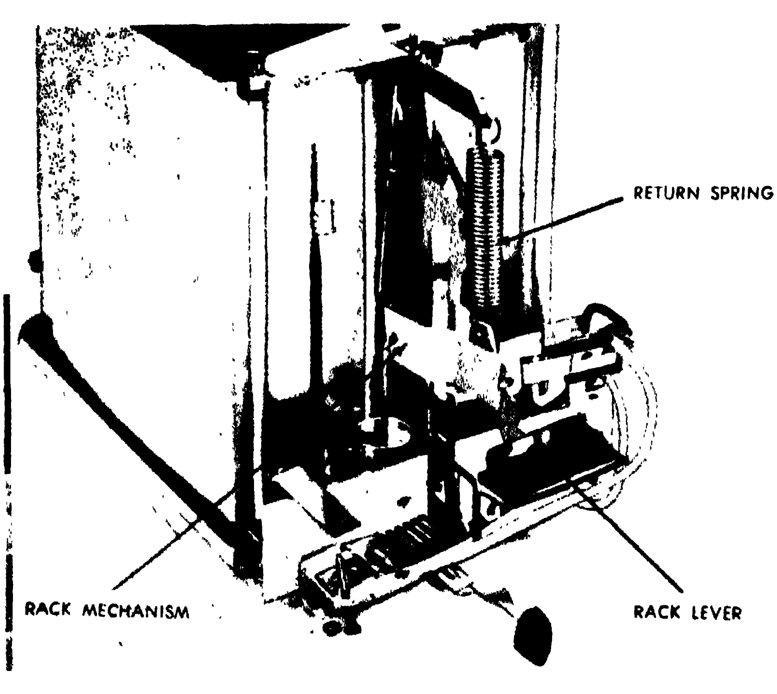


Fig. 3 (above) The non-automatic electric toaster with a lid open. The slice is placed against the rack

Fig. 4 (left) The mechanism of an automatic toaster. The lever actuates the switch and the timer

Water heaters

Basically, water heaters are of two types — immersion and storage. Immersion type water heater is also known as immersion rod (Fig. 6). It consists of (1) a metal tube (of high conductivity material like copper or brass) containing the heating element, (2) a terminal housing made of bakelite, (3) a three-core flexible cord, (4) a water level indicator, and (5) a three-pin plug. Immersion water heaters provide the most economical method of heating water, both in terms of its cost price and power consumption. But a sub-standard or a defective immersion heater is also a potential danger.

Immersion heaters are rated 1, 2 or 3 kW. The choice of rating, however, is not so critical; the higher rating will heat up water faster. For heating a particular quantity of water to the same temperature, the total electricity consumed will be approximately the same.

One of the common hazards in immersion water heaters is leakage current; this is a result of the water affecting the insulation. And if the earth connection is broken, it can give a shock to a person standing barefoot on the floor and dipping his hand in the water to check the temperature. When the insulation is totally broken, water can get charged with the full supply voltage, and a current path through the human body to the wet, low resistance floor of the bathroom may give a fatal electric shock. Accidents of this kind have occurred

HOW TO ENSURE QUALITY

The Indian Standards Institution standards specify three different test schedules — type tests, acceptance tests, and routine tests. The type tests are the most exhaustive; they include 20 to 30 tests covering the full range of performance requirements for a particular appliance, and are intended to check the basic design. The acceptance tests (usually about 10) are meant for inspecting a lot on a sampling basis. The routine tests (about five or six) are intended for 100 per cent inspection. They include visual inspection and safety tests.

We suggested last month that the Government order on compliance with ISI specifications should be implemented in a phased manner (see " The tug-of-war on quality ", SCIENCE TODAY, September 1977, p. 47). These phases could be (with minor modifications): (*i*) routine tests, (*ii*) acceptance tests, and (*iii*) type tests in that order. The routine tests do not require elaborate laboratory facilities, and can be provided in each major shopping centre. It would be fair to insist on this first phase implementation in about six months. It must be considered criminal on the part of anyone to manufacture or sell an appliance which does not meet the elementary requirements of safety.

Besides these routine tests, the ISI lays down specific tests for each type of appliance. What are these tests? For the toaster, for instance, the special test is called the toasting test. It specifies the size of the bread slice in numerical terms, but the result is only qualitative; it says that the browning should be even and of a reasonable texture and that it should not vary with supply voltage variations (within 5 per cent) or with the heating of the toaster. The endurance test prescribes that the toaster should be operated on a continuous cycle of heating (for three minutes) and cooling (for two minutes) for 500 hours. And at the end of the test, the toaster should be working satisfactorily.

For hot plates, the appliance is connected to the supply such that, with a specified vessel on the heating element, it takes 1·10 times the rated input. The endurance test consists of 500 cycles in which the hot plate is ON circuit for two hours and OFF circuit for two hours. During the test, 20 spillages each of 150 ml of 0·5 per cent solution of sodium chloride in distilled water at room temperature are made over the plate in one minute subject to the condition that (*i*) there shall not be more than four spillages in any 100 cycles, and these shall be equally spaced as nearly as possible over the time period, and (*ii*) alternate spillages shall be made on the plate in hot and cold conditions, that is, 15 minutes after switching on and 15 minutes after the switching off. Five minutes after each spillage, the hot plate should be subjected to a mechanical shock test by allowing a hardened steel ball of 75 mm diameter to drop freely six times from a height of 150 mm on to a 3 mm thick steel plate placed over the hot plate. At the end of the endurance test, the hot plate should be checked for proper functioning.

The routine tests for the electric iron include visual examination and inspection according to specifications for irons and other general tests. Other tests include measurement of heating up time and sole-plate temperature. The standards lay down that the heating up time should not exceed eight minutes. The specific tests include stability, cord guard, mass, measurement of temperature distribution, initial overswing temperature and heating up excess temperature (for thermostatic iron only), cyclic fluctuation of the hottest spot (for thermostatic iron only), temperature drop under load, mechanical strength, temperature rise and endurance.

Stability test for electric irons is meant to confirm that the iron does not overturn when tilted through 10°. The test for cord-guard is to check that neither the cord-guard nor the cord shows any damage through 20,000 flexing operations through an angle of 90°. The temperature distribution is measured at four specific points on the sole-plate. The temperature at any point should not differ from the mean by more than 6°C. For the measurements of (*i*) the initial overswing temperature, (*ii*) the heating up excess temperature, (*iii*) the cyclic fluctuation of temperature of the hottest point, and (*iv*) the temperature drop under load, elaborate procedures and apparatus are prescribed. However, no values are specified. Instead, the standards say that the values should be within the limits specified by the manufacturers. And that makes this portion of the test schedule redundant.

A drop test is also specified in which the iron, with the sole-plate horizontal, is dropped 1,000 times (a maximum of 20 falls from a height of 40 mm) on a steel plate, 15 mm thick and weighing at least 15 kg. During the test, the iron is operated and the sole-temperature is maintained as specified. After the test, a thermostatic iron should not change its calibration by more than + 10°C or — 20°C. The live parts should not be exposed by breakage or distortion of the enclosure. The temperature rise test is meant to determine the temperature rise of the rubber insulation of the internal and external wiring for which the limit is set at 40°C. In the endurance test, the iron is operated at 1·15 times the maximum rated input for 500 hours or 25,000 cycles of thermostat operation whichever occurs first. There should be no electrical or mechanical failures of the thermostat, nor any undue burning, pitting or welding of the contacts. The sole-plate temperature of an iron, with a thermostat, should not exceed 315°C average or a maximum of 350°C.

Special tests for storage water heaters include visual examination, pressure, mechanical strength, water capacity, input power, operating characteristics, abnormal operation and operation under overload conditions. Visual examination covers checking the quality of materials used, all seams and joints, sizes of inlet and outlet pipes, provision for draining, overflow, pressure regulating device, anti-drip device, inlet baffle, suitable labels and warnings of dangerous conditions.

But the most important one is the pressure test. For this, the container is subjected to twice the working pressure, subject to a minimum of 3·5 kg/cm^2 for the pressure type water heaters, and 0·8 kg/cm^2 for the free outlet type. The mechanical strength should be sufficient to withstand a load on top equivalent to the total weight of the heater plus water, when it is installed on a wall and filled full with water. The water capacity should not vary by less than 2·5 per cent or more than 10 per cent for the pressure type heater, and it should not be below 90 per cent of the stated capacity for the free outlet type heater.

The salient operating characteristics are the limits on idling losses, that is, the heat lost by conduction through lagging, check on calibration of the thermostat, overheating due to small frequent withdrawals of water, efficiency of the anti-drip device and diffusion performance. The abnormal operation tests consider events like short-circuit in the thermostat or heating on with no water in the container.

P.J.J.
S.T.P.

very often. Compliance with the ISI standards, at least in respect of high voltage test, electrical resistance and moisture resistance tests are, therefore, an immediate necessity.

There are certain other problems, like improper or inadequate chrome-plating, terminal housing made of non-electrical grade bakelite (thermosetting phenolic material) stuffed with a filler like saw dust, the use of cheap, sub-standard hardware resulting in the phase or earth wire getting disconnected, etc. When the plating of the copper tube containing the heating element is poor, the tube is subjected to faster corrosion, which ultimately leads to small holes in it. Once moisture or water enters this tube, the insulation starts deteriorating. While a number of brands of immersion water heaters are available in the market, our survey showed that only one brand carried the ISI mark. The quality of the rest left much to be desired, and, hence, basic safety standards should be enforced.

The most important precaution to be taken while using immersion heaters is that it should be dipped in water *before* switching the supply ON; before taking it out of water, the supply *must* be switched OFF. The same precaution should be followed even if one wants to put one's hand in the water to know how hot it is. The other precautions are: (1) the heater should be dipped in water only up to the indicated level and water should not be allowed to enter the terminal housing, (2) the heater should not be taken out of water immediately after switching off the supply, but allowed to cool down before taking it out; and (3) with hard water scales are formed on the metal tube, which should be periodically cleaned.

Storage type water heaters

Practically all storage type water heaters (Fig. 7) are automatic, that is, they are fitted with thermostats which control the water temperature. The temperature ranges from 32°C to 85°C. Storage type heaters are available in two versions — the displacement water type and the falling water level type. In the first version, hot water flows out when cold water is let in. The second type has an outlet valve at the bottom, and when opened, the water level inside drops as the water flows out. The former is more common and popular; it is also safer. In the falling water level type, there is a chance that if cold water is not filled after drawing hot water and the heating is left ON, steam may form inside and the pressure may damage the container.

The displacement water heater has two further variations — the pressure type or the controlled outlet type, and the free outlet type. In the pressure type, a valve fitted on the outlet water pipe controls the outflow of hot water. Because of this, the pressure inside the container is high and, if not controlled by means of a highly reliable thermostat and fitted with a good quality pressure safety valve, it can burst the heater and cause a serious accident. The free outlet type, has a valve in the inlet water pipe and the outlet pipe is free and open. And the outflow of hot water is controlled by the cold water inflow.

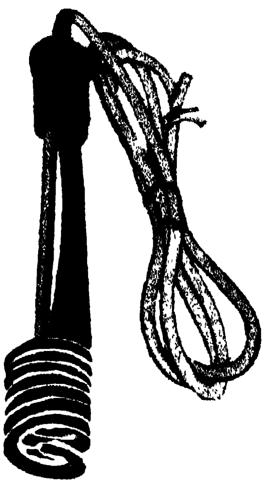


Fig. 6 (right) The immersion water heater

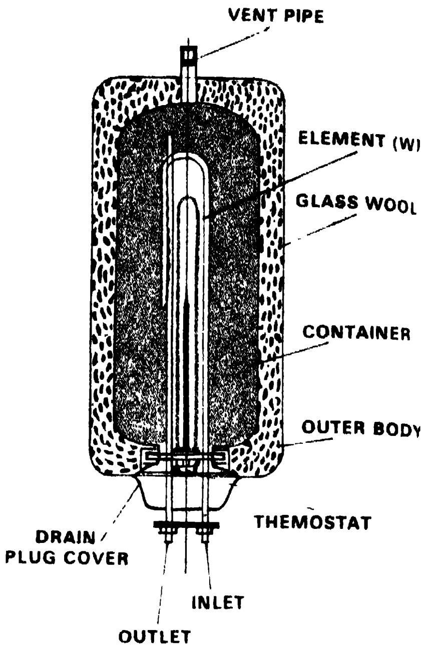
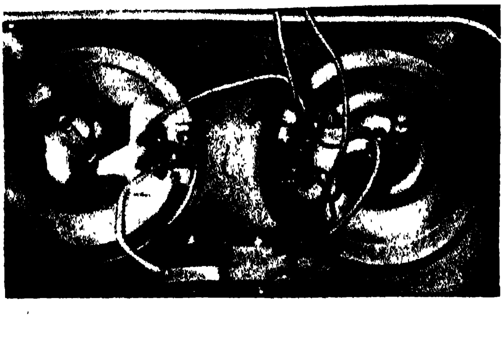


Fig. 7 (far right) A storage type water heater. The main parts are (1) a water container made of heavy gauge copper sheet of more than 90 per cent purity, (2) apparatus plate carrying the heating elements and thermostat, (3) outer body of mild steel sheet (of such thickness that the weight of the entire heater is supported by it rigidly), (4) a vent pipe or a pressure safety valve at the top, (5) glass wool, (6) drain valve to remove the dirt and the scales, and (7) pilot lamp indicator

Fig. 5 The hot plate where the heating elements are sealed



The rated input of storage type heaters is between 1 and 5 kW, depending on the heater capacity which ranges from 6 to 200 litres. The electrical input for a particular water capacity depends, to some extent, on how quick the water needs to be heated, and to a larger extent, on the type of use. For example, when hot water is required for bath by several persons in quick succession, a larger electrical rating would be necessary. On the other hand, if the hot water is required throughout the day for kitchen use, a lower electrical rating is advantageous.

But it is important to have proper "lagging" — the thermal insulation of glass wool used in storage heaters — particularly if one is keeping the heater ON throughout the day. This will keep down heat losses from the hot water and thus save on power consumption. The simple way to check the quality of lagging is to touch the outer body of the heater by hand; if one feels the heat coming through to the outer surface, it is not as good as it should be.

A common question faced by storage water heater users is whether the heater should be switched off after use or left on. The answer is 'switch off', if one requires hot water only for baths, in which case the thermostat is set at the highest temperature. It is not worth switching off, if one requires water frequently and that too at short notice.

There is a vital factor to be considered while fitting a pressure type storage heater. It is the head of water, or the pressure of water in the inlet pipe. If the inlet pipe is connected to the storage tank without any valve or tap, the pressure in the container can be dangerously high and it may develop leakages or even explode. Such accidents have occurred, though rarely. In such cases, a pressure regulating valve (similar in function to that fitted on the cooking gas cylinder) should be used on the inlet pipe. The valve regulates the pressure at the heater inlet pipe over a wider range of water head pressure.

Such a situation as mentioned above is a consequence of lack of awareness on the part of the consumers and indifference on the part of the manufacturers and suppliers. Somewhere in the product leaflet the maximum permissible inlet water pressure may have been stated, but an average user may not know its implications. The sale and installation of safety devices like pressure safety valves and pressure regulator valves in the inlet pipe must, therefore, be made obligatory. Pressure regulator valves are particularly necessary in high-rise apartments, where the water storage tank is invariably on the terrace, giving rise to a high pressure.

There are about four well-known brands of water heaters in the market. None apparently conforms to ISI standards, and it is doubtful if even the barest, but most essential, tests are carried out.

The authors acknowledge: Figs. 1, 2, 3, 4 and 5 from *How to Repair Small Appliances* (Vol. 1), by Jack Darr, D. B. Taraporevala Sons & Co Private Ltd, Bombay and Figs. 6 and 7 from *Electrical Appliances Repair and Maintenance* by K. Nath, Hind Pocket Books Pvt Ltd, Delhi.

learn while you play—12

B. D. KELKAR

A. V. DESHINGKAR

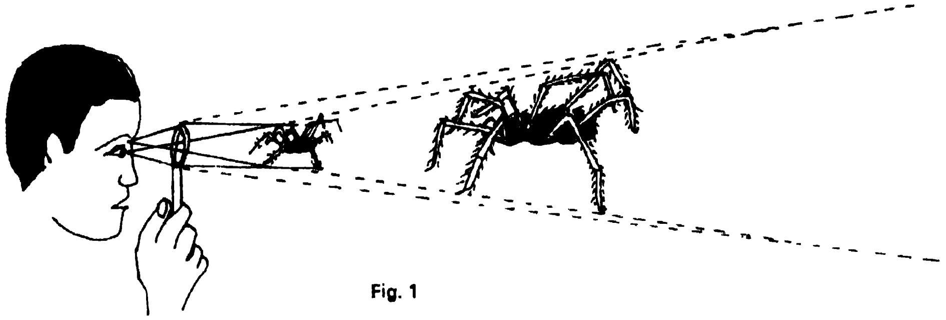


Fig. 1

Last month we had ended our trip through the world of light with mirages — the illusory images of things seen not where they actually are. But mirages are not the only instances of light's tricks. We see so many of them around us (in fact, we make use of many of them) that we tend to take most of them for granted. Let's take the simplest of them — the apparent change in the size of things seen.

If you dip a spoon into a glass of water, the dipped portion looks bigger than the actual size. Why does the enlargement increase or decrease if you shift the spoon's position forward or backward? The answer, of course, lies in the behaviour of lenses. A lens is a transparent medium — usually glass — that slows down a beam of light passing through it and thus bends it.

Why should this slowing down of light rays make it easier to see things? Or, to put it another way, what magic lies in a piece of glass that brings out the teeming life in a drop of water as in a microscope, or the distant stars a little closer to the astronomer's eyes looking through a telescope, or makes the blur of a distant object suddenly take a clear shape through the spectacles of a myopic or short-sighted person?

The clue to this magic is held by 'refraction' — the bending of light rays as they pass through two transparent media of different densities. The reduction in the speed of light (as light rays pass from air into the glass) is accompanied by a bending of the light rays; this occurs again as the rays emerge from the glass into the air and enter our eyes. In the case of ordinary glass, the two 'bendings' balance. But in a lens, the two sides of the glass are ground to an angle which makes the rays travel off in a new direction. In a magnifying glass — the simplest form of lens, perhaps — this 'deceitful' bending of light rays is deliberately achieved to make it appear as if they are coming from a closer or larger object (Fig. 1).

A magnifying glass has two sides curved such that it is thickest in the middle; it is known as a double-convex lens. Another type of lens — thinnest at the centre — is known as double-concave lens. If one side is flat and the other concave or convex, the term is plano-concave or plano-convex, as the case may be. Actually, to understand how light rays bend in a lens of convex or concave curvature, all we have to do is get hold of a pair of prisms. A convex lens, then, would be similar to the pair of prisms placed base to base (Fig. 2). When parallel beams fall on the set of prisms, the rays bend towards the base; they will meet at the focus F which is on their common axis. And that's exactly what happens in the case of a convex lens. On the other hand, a concave lens is like the pair of prisms placed apex to apex (Fig. 3). Here, too, the rays bend towards the base, that is, diverge outwards, and when traced back will appear to meet at the focus F.

The image seen through a concave lens appears smaller than the actual size. Fig. 4 shows why. Now take a convex lens and view an object through it by placing the lens at different distances from it. Here you will see a curious phenomenon: the object will be seen either upright and enlarged or inverted and reduced (Fig. 5). If you study the diagram, you will see that to get a magnified view, the object must be *inside* the focus of the lens. You can easily verify this. Hold the lens in a darkened room and let light from a window shine through it on to a piece of plane paper. You can see a small image of the window and the objects outside on the paper. Of course, the paper must be held at the correct distance, for example, for nearby objects, the paper must be farther away from the lens. You will notice the image on the paper is upside down (Fig. 6). And, that is the principle of the photographic camera (Fig. 7).

A magnifying glass focuses not only the visible rays but also the

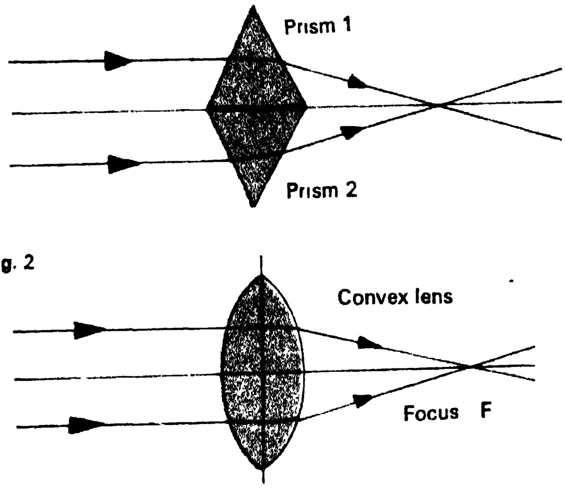


Fig. 2

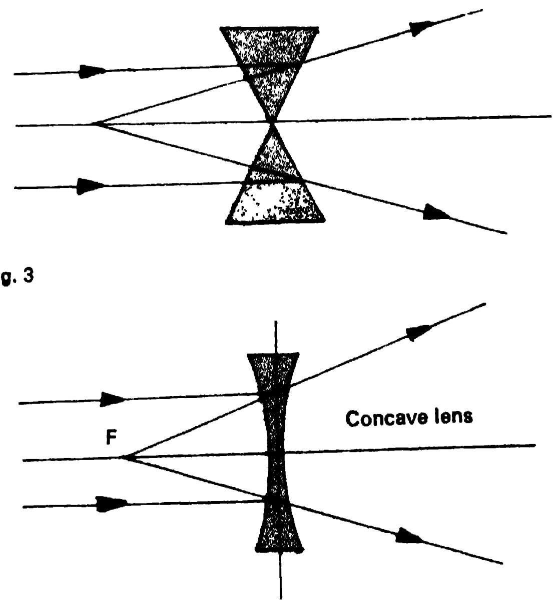


Fig. 3

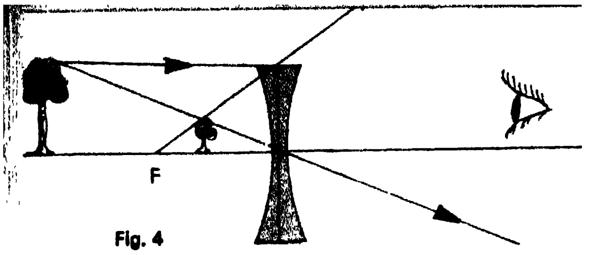


Fig. 4

invisible infra-red heat radiations. It can be proved easily. Hold a lens between the Sun and a piece of paper. First a small point will appear on the paper (this is the image of the Sun) and in a few minutes the paper will catch fire at that spot. This is why this sort of lens used to be known earlier as ' burning glass,' ' converging lens ', etc.

The distance between the paper and the lens in Fig. 6 is known as

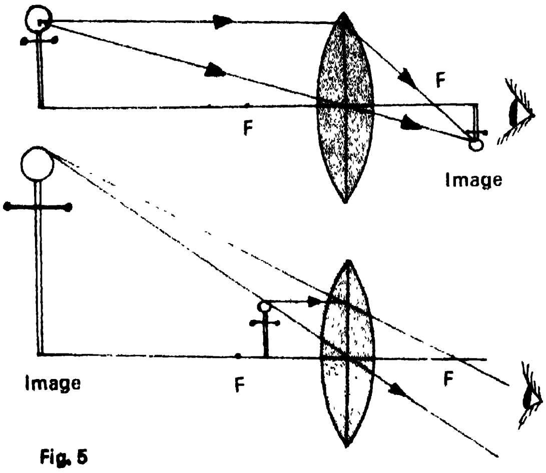


Fig. 5

the ' focal distance ' and depends on the curvature of the lens's sides. The human eye, too, has a lens and it has the remarkable ability to shape its sides to sharper or flatter curvature to adjust to the necessary focal distance. In the human eye (see box for a detailed description of its parts), the lens is attached to the inner walls of the eyeball by fine suspensory fibres. These fibres are normally held tight; if they are loosened, the eyeball becomes rounder, and the rounder the lens the shorter its focus. While looking at distant objects, we do not need to change the shape of the eye lens, but to see nearby objects, we have to alter the lens shape by loosening the suspensory fibres (by moving the ciliary muscles). This is called " accomodation ".

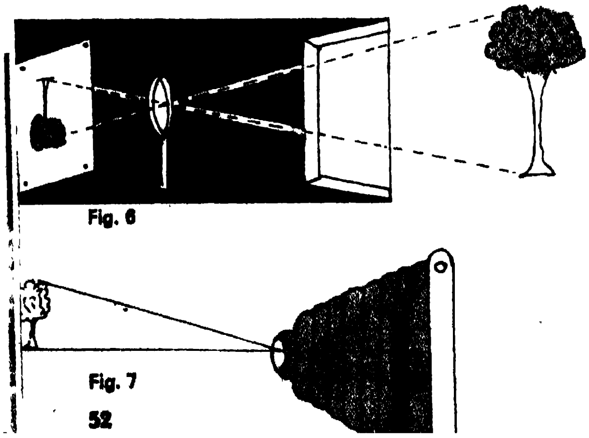
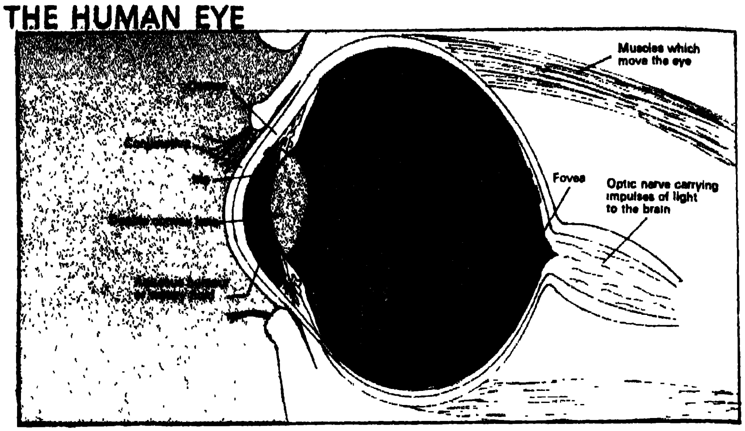


Fig. 6

Fig. 7

THE HUMAN EYE


Muscles which move the eye
Fovea
Optic nerve carrying impulses of light to the brain

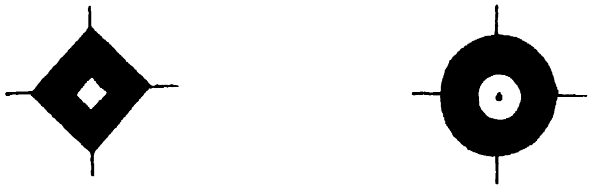
Optically, the eye is like an exceptionally fine camera with an elaborate lens system on one side and a sensitive screen known as the retina on the other. Light rays from objects pass through the refractive media of the cornea, the aqueous humour, a crystalline lens and the vitreous humour and are focused on the retina. The iris diaphragm opens wider for faint light and closes down to a pinhole for very bright light.

In the retina, light pulses are received by tiny cones and rods whose function, it appears, is to change the light into electrical impulses. Each cone and rod is connected with an individual nerve to conduct the impulses to the brain. How these electrical impulses are produced by the cell-like structure of cones and rods and how the impulses are interpreted by the brain are still not fully understood. It appears that the cones respond only to bright light and are particularly responsible for the determination and distinction of colour, whereas, the rods are sensitive to feeble light and very slight variations in the intensity.

At the very centre of the retina is a small yellowish spot called the fovea. This small region contains a large number of cones but no rods. Near the fovea on the retina is a small region called the ' blind spot '. This spot is insensitive to light.

We can easily verify the existence of the blind spot. Look at the drawing below. Close your right eye and hold the page at an arm's length and look at the circle with your left eye. You can see both the circle and the square from this distance. Now bring the page slowly towards yourself with the left eye still fixed on the circle. When the drawing is about 25 cm from the eye, the square disappears.

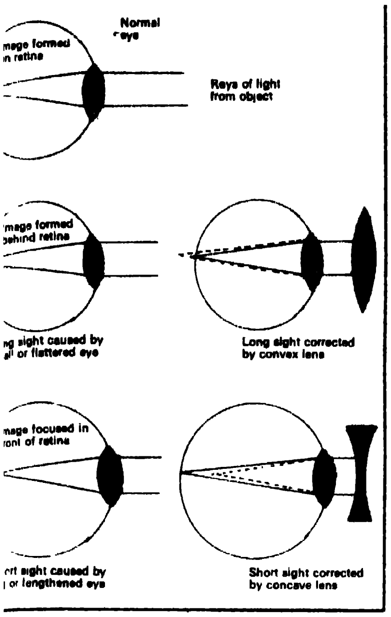
Repeat this experiment with the left eye closed and the right eye focused on the square. As you bring the drawing closer, this time the circle will disappear.



But, then, not all eyes can adjust their vision by accomodation alone. There is the long-sighted person whose eyeballs are smaller than normal, which means the retina is a little too close to the lens; as a result, light rays focus behind the retina. The short-sighted person has eyeballs slightly larger than normal so that light rays focus at a point ahead of the retina. Fig. 8 shows how spectacles of different lens curvatures correct these focusing defects.

Optical illusions

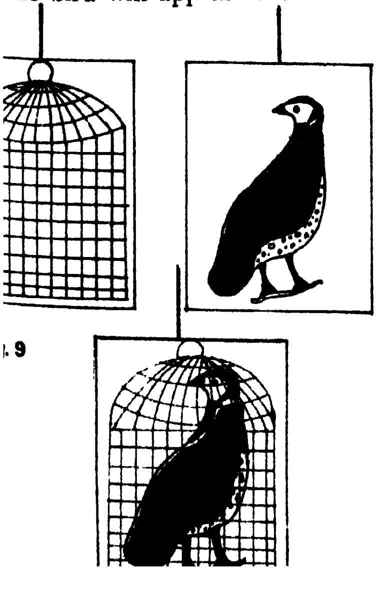
How reliable is our vision? Visual information comes through the light reflected by objects which enters the eye and reaches the retina. But that is only one part of the ' seeing ' activity. The brain must interpret this information and this is where it may fail to perform correctly. Distances are misjudged, shapes are distorted, and even we tend to see things that are not there. The chief reason behind such


Normal eye
mage formed n retine
Reys of light from object
mage formed behind retina
ng sight caused by ll or flattered eye
Long sight corrected by convex lens
mage focused in ront of retina
ort sight caused by or lengthened eye
Short sight corrected by concave lens

j. 8

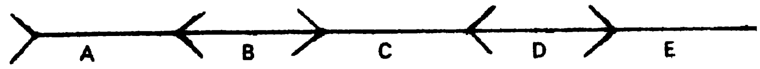
illusions lies in our unreliable sense of perspective — that is, what we *believe* to be the relationship between size and distance. A number of such optical illusions — some very famous — are shown in the following pages. You can spend hours on them and, if you wish, confound your friends with them. And you may try to work out what gives rise to these illusions. To be honest, many of these illusions can be found reproduced in textbooks of psychology. Many psychologists believe our ability to interpret shapes and sizes is conditioned by the environment in which we are brought up.

There is also the illusion of movement that can be created by moving different images in rapid succession. A simple experiment is shown in Fig. 9. On one side of a cardboard is a picture of a cage and on the other side is the picture of a bird. If you rotate the cardboard fast enough (by suspending it from a thread), the bird will appear to be inside

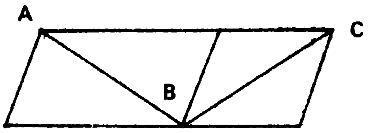


j. 9

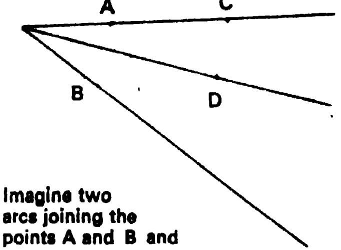
OPTICAL ILLUSIONS



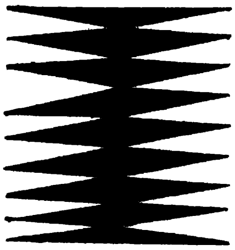
Are the segments A, B, C, D and E of the same length?



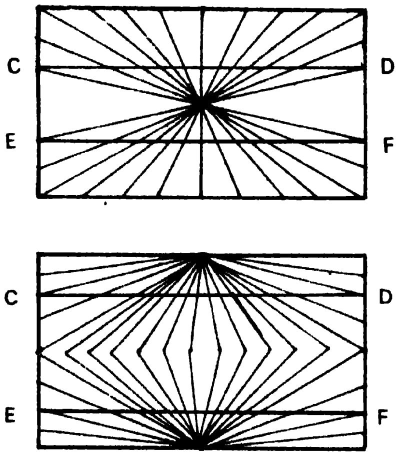
Are the diagonals AB and BC equal?



Imagine two arcs joining the points A and B and C and D. Are they equal?

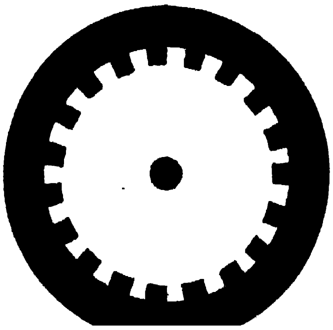


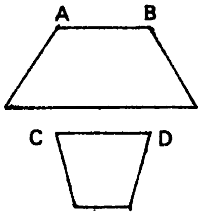
Look at this pile of diamond-shaped figures. Do you think the height of the pile is the same as its width?



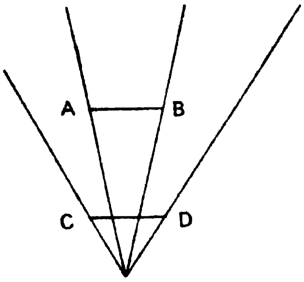
In both figures, lines CD and EF are parallel.

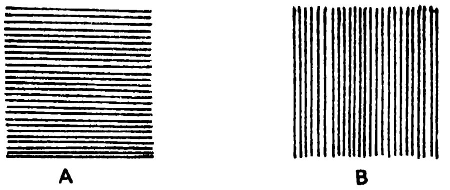
Hold the page and move your hand rapidly in circles and the gear wheel will seem to rotate in the opposite direction.



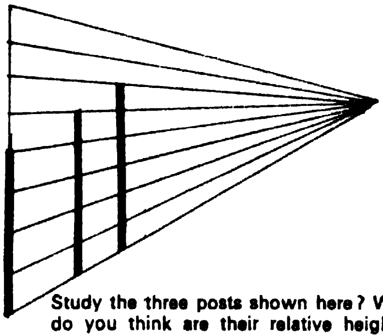


Is AB equal to CD in these two figures?

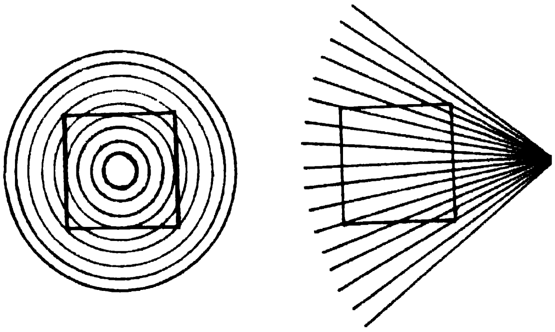




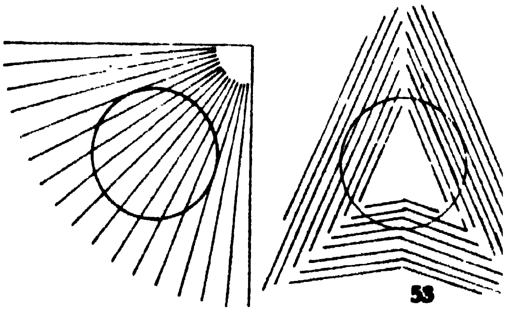
Two piles of parallel lines are shown here. Do you think the width of pile A is the same as that of B?



Study the three posts shown here? What do you think are their relative heights? Now verify by measuring them with a scale.



These two figures show how distorted appearance of regular geometrical figures is achieved by modes of surrounding lines. Above, both are perfect squares; below, both are perfect circles.

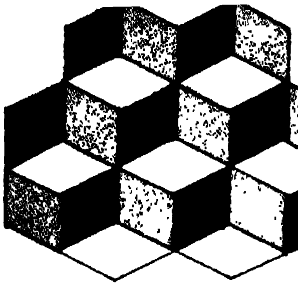


the cage. Perhaps now you can understand how cinematograph films create the illusion of movement. The movie camera captures the action by taking a series of still pictures at regular intervals; the projector flashes these pictures on the screen at the same frequency. The illusion of movement arises from the phenomenon of ' persistence of vision ' of the human eye. The still pictures appear on the screen many times a second — for normal movement, the rate is 24 frames per second; there are 16 frames per 30 centimetre of film — and the dark intervals also appear the same number of times, but we see the image as a continuous action and not as separate individual still pictures because the eye retains the image of the earlier frames by the time the subsequent frames come up.

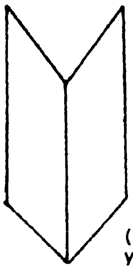
Meanwhile, let's end this article with a few comments on the speed of light. How great is the speed of light? Roughly, it is 1,86,284 miles or about 3,00,000 km per second. This tremendous speed of light is used by astronomers to give a measure of the distance of heavenly bodies. The light from the Sun takes some eight minutes to reach the Earth. And that's insignificant compared to the stars whose distances have been calculated by thousands and even millions of light years. (To get the distance of one light year in kilometres, you will have to multiply 3,00,000 by 60 × 60 × 24 × 365 !)

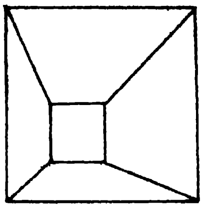
Light is the fastest moving agency in the universe. No material particle can reach the speed of light, because if it did, it would become infinitely heavy. The explanation lies in the domain of higher physics and we cannot go into it here.

AMBIGUOUS IMAGES

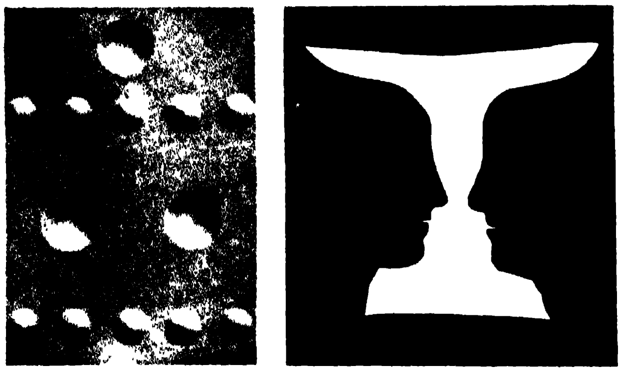


Observe the cubes. They will appear stacked one over two over three — total six cubes. Go on turning the figure by 30° and each time you will see *seven* cubes stacked two over three over two.

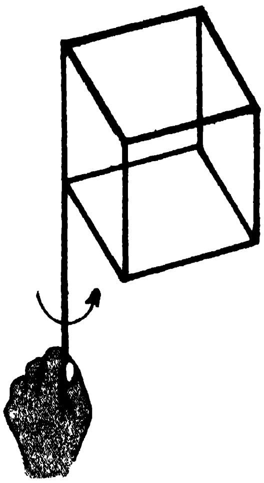




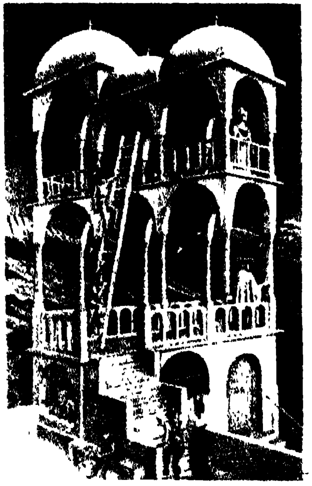
(Left) Here's a folded sheet of paper. Can you tell if the opening of the fold is towards or away from you ? (Right) You can see a tapered box. Which way is the opening ? Towards you or away from you ?



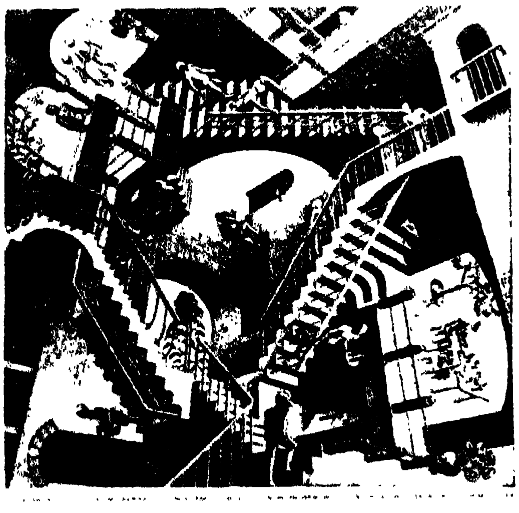
(Left) Crater illusion. Turn the photograph upside down and the craters will look like domes. (Right) Is it a vase or two profiles facing each other ?



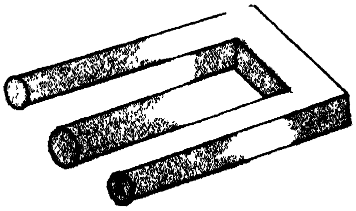
(Above) Make a cube (3 cm to a side) of wire and extend one side for holding at a distance of 40 cm from your eyes. Imagine the farthest corner to appear as the nearest one. Now turn the cube about its horizontal axis and you will feel the cube rotating in the opposite direction



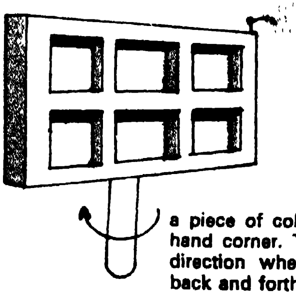
The ambiguous lithographs of the late Dutch graphic artist Maurits Escher. At left, "Belvedere ", done in 1958, uses the reversible-perspective illusion to draw the " impossible architecture of the building ". The figure seated at bottom is playing with a cube similar to the one at right. (Below) " Relativity ", a 1953 lithograph, shows another impossible design, based on the reversible-perspective of " up-and-down "



(Below) An illustration of the 'impossible' made possible by drawing a three-dimensional object in two dimensions



TRAPEZOIDAL WINDOW



Cut a window (12 cm × 12 cm) from 1 cm thick thermocole sheet. Paint the depths in grey and black as shown in the drawing. Fix a nail so that the window and the nail can rotate freely in a hole drilled in a wooden block.

Place the frame on a table in a darkened room, and light it by front and side illumination from two lamps shielded from the viewers' eyes.

Rotate the model slowly. You will feel the window rotating first in one direction and then in the opposite direction. Paste a piece of coloured paper (or balloons) at the top right-hand corner. The paper will appear to rotate in the same direction whereas the window model will still oscillate back and forth.

You can heighten the effect if you can connect the model to a slow-speed cell motor.

BOOKS

Host-specificity in insects

INSECTS AND HOST-SPECIFICITY (Proceedings of the symposium on " Problems of Host-specificity in Insects " held at the Entomology Research Unit, Loyola College, Madras, January 1976), ed. T. N. Ananthakrishnan, The MacMillan Co of India Ltd, 1977, pp. 127, price not mentioned

In recent years, publication of proceedings of symposia has become a (welcome) vogue, at least at the international level. Generally, such publications are pre-planned (with adequate if not generous financing by gubernatorial agencies and/or the publishers) to incorporate generalised introductory lectures for the various sub-heads/sections, apart from the specialised papers. The actual proceedings are reported almost verbatim, and the participation is usually glamorous! What results is generally a conglomerate of delight and instruction even to the layman, and of immense value to the specialist.

At first glance, *Insects and Host-specificity* seems to cover a lot of ground with a galaxy of contributors, and a few big names thrown in. But a closer scrutiny reveals the limitations in scope, expertise and even region-wise representation. A few renowned names in the field are conspicuous by their absence. Of the subject, some areas receive relatively parsimonious attention.

Host-specificity in insects is a fascinating field of research which can yield both academic insights and scientific techniques for better pest control. Insects choose particular plant(s) to feed and thrive on, based on the occurrence of various chemical and nutritional allurements in the latter. Interestingly, apart from, and sometimes in spite of, adequate nutritional correlates, a host with secondary plant substances (with no functional significance to the plant and of no nutritional value to the insect) determines the initial choice or rejection of the host plant by the insect. Interactions of the intrinsic, extant physiological state, and the behaviour and life patterns of the insect with the chemical constitution and ecology of the plant also come into play in the final establishment of an insect on specific host plant(s). Field bionomics, that is, associations and inter-relationships between specific insects and plants in nature forms the first step or the launching pad for research in host-specificity.

Dr. Ananthakrishnan's compilation contains several contributions in the last category. The same cannot be said of the other, equally important, aspects. Physiological and behavioural aspects of host selection receive comparatively inadequate coverage. There is no full-length paper on host-seeking behaviour in agricultural pests and just one paper each on secondary chemical substances, morphological correlates and other chemical constituents (growth regulators). These and some other papers, for example, on biological control, vectors and parasites, provide redeeming variety from the plebeian recitations of bionomics and/or some banal reviews.

A sore point is the extreme brevity of most papers, attributed by the editor to the economics of production costs. This forced condensation of material is perhaps responsible for the dubious hue of the more sketchy presentations. Presumably, also, similar or other reasons have prevented a more balanced and broader participation. Recent trends such as the application of the computer technology to the construction of models of insect host-seeking behaviour in the concatenation of ecological parameters — which are being tackled in India also — are not even mentioned in any contribution. Similarly, the importance of electrophysiological studies, though gratuitously mentioned in a couple of papers, is neither sufficiently elaborated nor even adequately introduced for the uninitiated by reference to the great pioneering achievements in this field (for instance, of the Danish scientists). The cross-section provided by the book of the many-faceted problem of host-specificity in insects is, therefore, neither sufficiently comprehensive nor even representative of all those aspects which are actually being studied in India itself.

The absence of discussions at the end of each contribution is also a lamentable omission, for perhaps the liveliest and most valuable insights often emerge from the loud, free-thinking stirred by the debates following the presentation of a paper. In fact, the compilation can hardly be called " Proceedings " in the absence of these invigorating tail-pieces. The editor, however, has been far-sighted in giving reference citations in full.

The book has its value as a compendium of pest-plant relations specific to this country, specially to new workers in the field. Its interest, readability and digestibility for the layman or any distinctive specialist value in the individual contributions is restricted to a few select papers as a whole and to patches only in others. With the given subject, more funds and wider participation, the editor, who is well known in Indian scientific circles as an indefatigable crusader and incomparable organiser, could undoubtedly have produced a memorable volume. Dr. Ananthakrishnan nevertheless deserves congratulations for at least attempting to focus the spotlight on some of the current Indian research in this interesting field.

R. N. SHARMA

[Dr. Sharma is Entomologist with the National Chemical Laboratory, Pune.]

On gene expression

CONTROL OF GENE EXPRESSION by Norman Maclean, Academic Press, London, 1976, pp. xi + 348 (£ 7·80)

The control of gene expression is still not well understood, whether in lower or higher organisms. There are some vague ideas on how the control of gene expression is accomplished in bacteria. However, we are ignorant of this process in higher organisms, that is, eukaryotes, except that it probably involves complex processes. Therefore, the author has not devoted the book to explain how gene expression is controlled in eukaryotes but has rightly laid stress on the discussion and comparison of the experimental systems currently being used to probe this problem.

The book, therefore, mainly deals with the various eukaryotic experimental systems — from the simple systems involving only one type of protein (immunoglobins, lactate-dehydrogenase, hemoglobin, etc) to systems not yet well understood in molecular terms (slime moulds, *Acetabularia*, *Hydra*, imaginal discs of *Drosophila*, etc) through systems of limited complexity (pancreas, yeast, muscle, *Aspergillus*, *Neurospora*, etc). The discussion on the imaginal discs in *Drosophila*, in chapter 5, is excellent.

SUBHASH S. ARORA

[Mr. Arora is an Indian Council of Agricultural Research scientist-designate with the Department of Genetics, Haryana Agricultural University, Hissar.]

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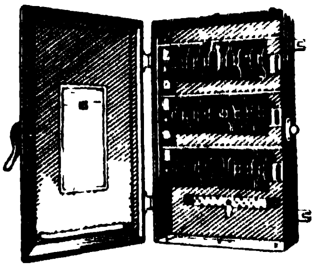

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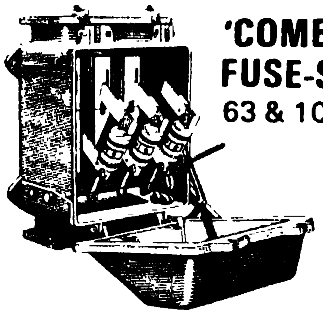

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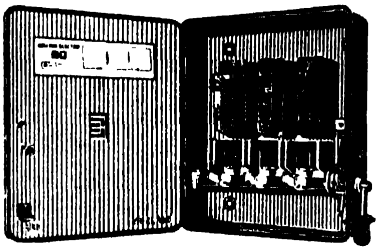

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QUESTION & ANSWER

What are the distinguishing characteristics of the various kinds of cassettes in the market ?

With ever so many types of cassettes in the market and all kinds of claims made on their behalf, the cassette-recorder owner is likely to be foxed, or at least bewildered. He will do well to remember that a cassette will give the performance claimed for it only when the recorder has the necessary adjustments (such as for ' bias level ').

The magnetic recording cassette basically consists of a non-magnetic tape such as cellulose acetate, polyester or PVC coated with the very fine particles of magnetic material such as ferric oxide. This tape is moved at a constant speed across an electromagnetic recording head. The magnetic flux provided by the recording head, representing the audio signal to be reproduced, provides the corresponding magnetic pattern on the very fine magnetic particles on the tape. In playback operation, the prerecorded magnetic pattern is scanned by the same or similar head which converts them into corresponding electrical impulses. This is what is basically done by a cassette tape recorder.

In practice, things are not that simple. The relationship between the recording head and the magnetic tape is very complex. The frequency response, for audio-frequency spectrum, of any tape is far from ' flat '. Thus, all the tape recorders have an ultrasonic frequency oscillator which supplies the ultrasonic bias current to the recording head along with the signal to be recorded. The magnitude of this bias signal is much more than the audio signal to be recorded. This bias signal ' churns up ' the fine magnetic particles on the tape and demagnetises them, so that the recording signal has a much easier job to do. Then comes the equalisation of the frequency response. This is done in two parts. While recording and while playing back, the playback equalisation is standardised so that a cassette recorded on one recorder can be played on another.

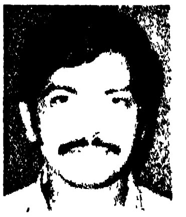
The third thing is the dynamic range, ie, the span between the softest and the loudest signal the tape can handle without any distortion. By increasing this range, the signal one records can rise higher above the background noise level, called ' hiss ', present on all magnetic tapes. This improves the signal-to-noise ratio, and one hears less hiss on low volume passages of recording. (The above is also applicable to reel-type tape recorders.)

These characteristics, ie, the bias, equalisation, dynamic range and hiss, are where the different cassette types and brands are at variance with one another. " Extended frequency ", " high output ", " low noise ", " super ", " ultra ", " dynamic ", " high energy ", " cobalt doped ", are the different epithets representing some of these characteristics of the magnetic tape. In most of these cassettes, ferric oxide is the basic magnetic material. The finer the magnetic particles and the greater the density of these particles, the lower the noise, the more the output, ie, extended dynamic range and better high frequency output. Chromium dioxide is one of the new magnetic materials used in cassette tapes. The output of these chromium dioxide cassettes is quite high. The frequency response, on the higher side of the audio spectrum, is much better in comparison with ferric oxide and its derivatives.

Different types of ferric oxide cassettes require different low, medium or high bias levels. The chromium dioxide cassettes require still higher bias level. Except for professional cassette recorders, the direct or indirect adjustment of the bias level to suit the type of cassette used is normally not provided by the recorder manufacturer. Almost all standard portable or average household tape recorders work on fixed bias system and their electronic amplification works on limited audio frequency spectrum. Thus, the modern tapes, whether derivatives of ferric oxide or chromium dioxide, may not provide all the advantages claimed for them unless the recorder has the provision to optimise the bias level. On the other hand, the chances are, these modern cassettes may give sound inferior to their older counterparts.

NOTE: Except for chromium dioxide, all other magnetic materials, as explained above, are also used on conventional reel tapes. Chromium dioxide gains its importance only because the cassettes are operated at the speed of 1 7/8 i.p.s. This speed is low in comparison with reel tapes. At the reel tape speeds, the characteristics of ferric oxide type tapes become comparable with chromium dioxide.

ANIL V. BORKAR



[Mr. Borkar (30), a radio and electronics engineer, is technical director of an industrial electronics concern in Bombay. He holds patent rights for devices like a radio-controlled electronic switch for radio and TV sets (developed when he was 18), fire alarm and photoelectric device. He has won awards from Esso, the Inventions Promotions Board and the Mahratta Chamber of Commerce and Industries. He has been associated with SCIENCE TODAY almost since its inception, as a contributor to " You Too Can Do It."]

" Do you have one that will remind my wife she has overdrawn ? "

BRAIN TEASERS

CAROM WITH A DIFFERENCE : Mr. Shambhu is an unorthodox referee. For example, in his game of carom, he uses only white pieces, 25 in all. Two players are to play one strike alternately. For each successful strike, a player gets one point and for each unsuccessful one, the opponent gets one point. In one game, there were seven unsuccessful strikes in all and when the score was 9-8, Mr. Shambhu closed the game and declared the one who got nine points the winner. Was he the first striker or the second?

V. A. SHENAI

(Solution next month)

Solution to last month's Brain Teaser :

Swamiji's devotees

Let there be m men, each getting x flowers.

Then $mx + (12 - m)(x + 2) = 142$

Simplifying, $6x - m = 59$

or $x = 9 + \frac{5 + m}{6}$

For m and x to be integers, for men to outnumber women and for m to be less than 12, m is 7 (and hence there are 6 women) and $x = 11$. Hence, each man got 11 flowers and each woman, 13.

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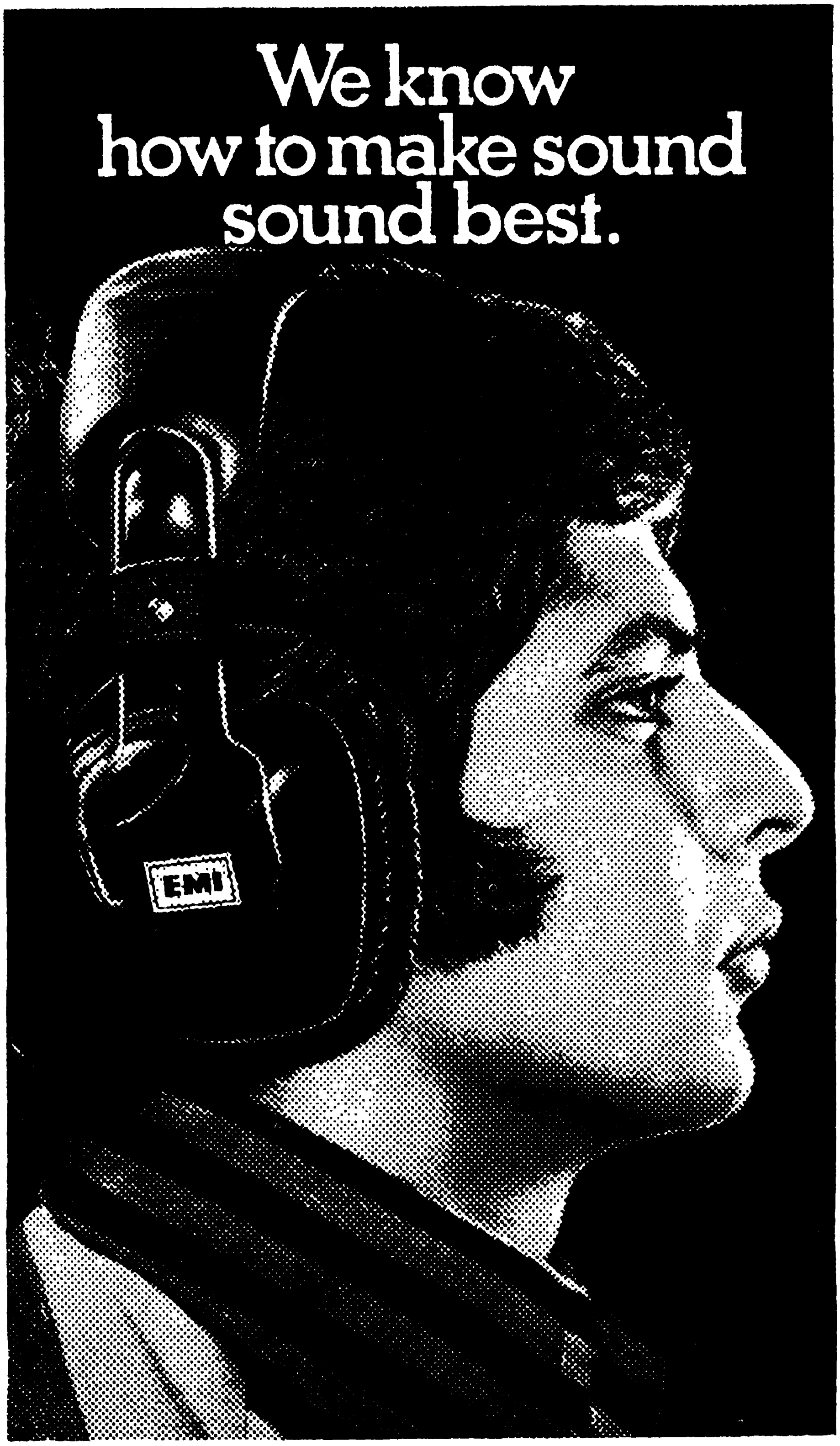

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DRY CELL RECHARGER

The name "dry cell" is really a misnomer, as no cell which is dry will deliver any appreciable current. The most widely used and readily available dry cell is a special form of the Leclanche cell. Since this type of cell is relatively very light and portable, it has practically replaced other types of primary cells. The main cause of these dry cells becoming exhausted is their really becoming dry.

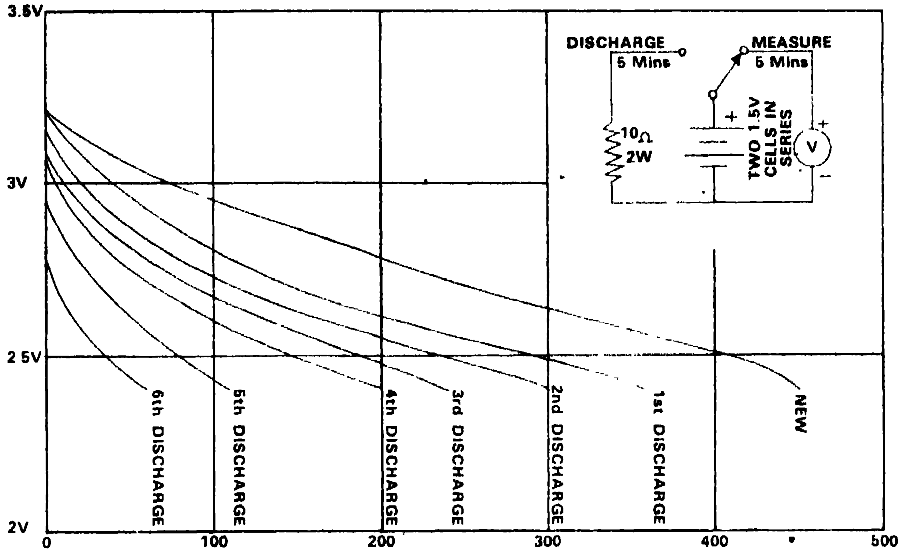
The anode is the zinc container of the dry cell; the cathode is a carbon rod located axially in the zinc container. The paste-like mixture of manganese dioxide, ammonium chloride and crushed coke, pressed solidly into the container between the carbon rod and the separator, acts as an electrolyte. The top of the container is sealed with tar or a similar compound.

The emf of torch cells, when new, is from 1·5 to 1·6 volts. This emf drops even though the cell remains idle for a long time. The shelf life of the cell is limited.

As the cell delivers current, due to electrochemical reaction within the cell, the manganese dioxide loses oxygen while the zinc of the container is oxidised which gets dissolved in the electrolyte. If this process continues for a long time, the zinc container develops cracks or holes and thus can't stop the electrolyte from leaking out. If you recharge the cell before this reaction proceeds very far, you can restore the working of the cell.

Recharging the dry cell is a process similar to electroplating. The recharging current, which is in the reverse direction (that is, cathode to anode) to the flow of current inside the cell while the cell is in use, ionises the dissolved zinc oxide from the electrolyte and deposits the zinc back on the zinc container. The oxygen, in the same way, is returned to form the manganese dioxide. The quality of the recharged cells depends upon their age and how they were used when they were new. Those cells which have been used in the normal manner and then put to charge soon after do take and hold the charge. A fully discharged cell will not be able to hold any charge. To get a longer recharged life from a cell, you must interrupt its service life when its voltage drops just below 1·2 volts. Recharge the cell, depending upon its type No., for about 6 to 12 hours and put it back into service. In this way you can extend the life of these cells by about three-fourths. However, these recharged cells have a comparatively poor shelf life.

DISCHARGE CHARACTERISTICS
WITH CELL TYPE 1035



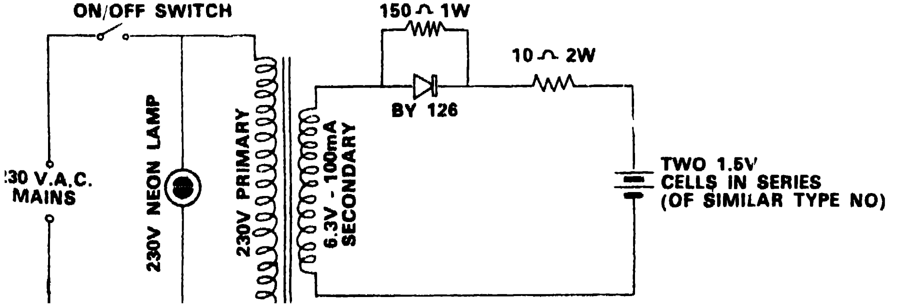
INTERRUPTED DISCHARGE OF 5 MINUTES INTERVAL TIME MEASUREMENT CONTINUOUS

The dry cell recharger, as explained below, is suitable for simultaneous charging of two 1·5 volt cells connected in series. It has very few components. The standard step-down transformer provides 6·3 V AC to the silicon rectifier, BY 126. The 10 ohms 2-watt resistor in series with it is for limiting the charging current. The 150 ohms 1-watt resistor, in parallel with the rectifier, provides about 10 per cent ripple current. This ripple current, along with the DC current, helps even out the deposition of the zinc on the inside of the zinc container.

Experimentation: In portable cassette recorders, record players, battery operated toys and radios, the cells are generally never used continuously. Thus, the cells get sufficient time to recover when not in use, and provide comparatively longer useful life than if they were used continuously. To evolve the discharge characteristics of two cells in series, under various conditions like new first charged, second charged, cells under accelerated discharge condition etc, the following experiment was done. The changeover switch was alternatively kept in "measure" and "discharge" positions for five minutes. Every time the switch is in "measure" position for five minutes, the cells get sufficient time to recover as the current drawn by the voltmeter is negligible. This procedure was continued while taking the voltage readings, till the voltage shown by the voltmeter dropped to 2·4 volts. When this level is reached, both the cells were removed and put on the charger continuously for nine hours. After the charging period, the cells were kept idle for about an hour and then subjected to the same discharge pattern. The discharge characteristic curves (see above) show the usefulness of the charger.

(*Note:* Don't keep the dry cells in the charger when the charger is not connected to the mains supply. Otherwise, the cells will discharge through the two resistors and the transformer winding.) Approximate cost, Rs. 25.

The DC charging current (1) when the discharged cell emf is 2·4 V = 25 mA approx. (2) when charged cell emf is 3 V = 12 mA approx



You will need:

Silicon Rectifier: BY126 or BY125, 1 no;

Transformer: Pri: 230VAC;
Sec: 6·3V — 100mA, 1 no;

Resistor: 10 — 2W, 1 no; 150 1W, 1 no;

Misc: 230V neon lamp, battery holder, two cells, ON/OFF switch, wires, solder, screws. suitable enclosure, etc.

ANIL V. BORKAR

Cell type no.	Recommended charging duration
1015	4—6 hours
1035	6—

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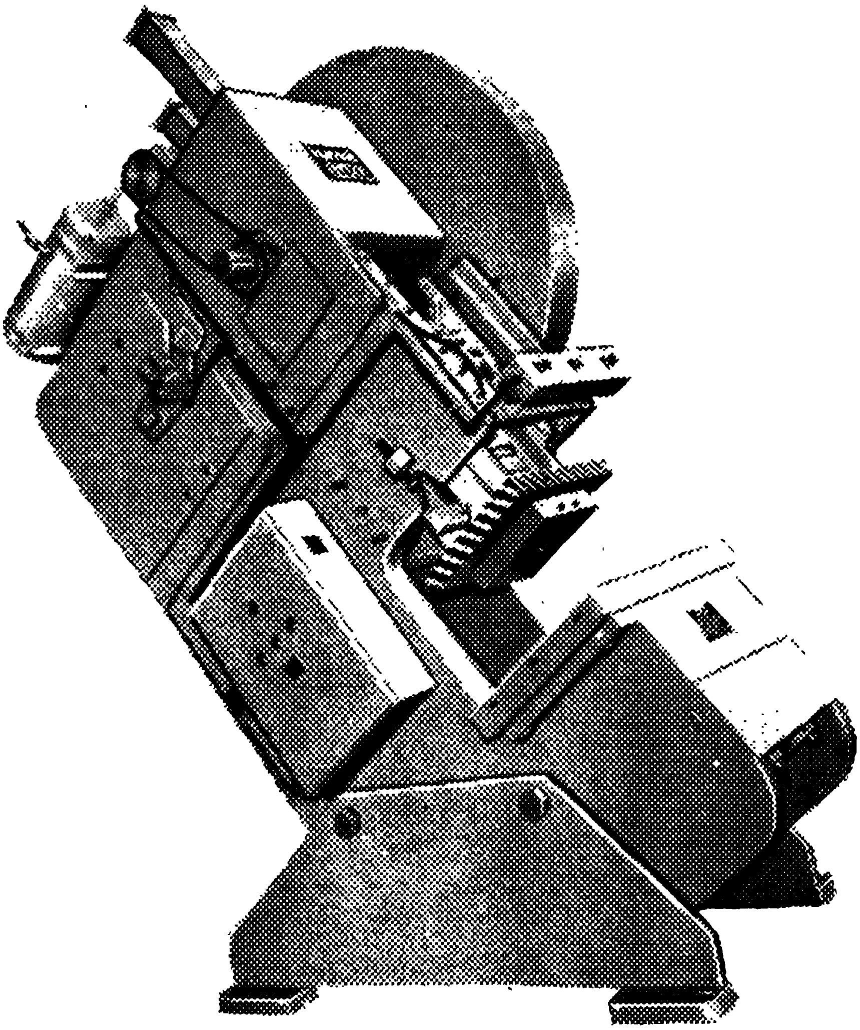

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TELL US WHY...

... they say animals use their tails for just about every purpose imaginable?

Because it's true. Take a squirrel's bushy tail. It is a steering rudder when the squirrel is making its big arboreal jumps and a balancing parasol when the squirrel is picking its way along fine twigs. When squirrels miss their footing and fall (they sometimes do), the plumy tail acts as a parachute so effectively that squirrels often plunge from heights of 15 or 18 metres without suffering any injury. Then, the bushy tail is a warm wrap-around in cold weather. An Arctic fox, for instance, sleeps with its tail curled around over the tip of its nose. A tail is also of incalculable help in making a predatory enemy misjudge a pounce. a predator, rushing after its victim, is likely to jump at the waving tail; all it gets is a mouthful of tail fur while the tail-owner gets away.

Is it true that mice use their tails to get food out of inaccessible places? Often one can hear animated debates on this point. Well, it's true. If a mouse finds an unstoppered jug of, say, molasses, it will sit atop the neck, lower its tail into the jug (like a man lowers a bucket in a well), and haul up the sweet stuff tailful by tailful.

Or take the case of the kangaroo's great heavy tail. It leans back and props itself on it, as a man does on a shooting stick. Even many lizards use their tails that way. The original monster lizards almost certainly swung their tails as weapons, in a carry-over from the tail-swinging technique of fish. The crocodile, too, uses its tail as a weapon. So does an ant bear. It thwacks with its tail as powerfully as a bear with its forepaw.

Tails serve as fly-swatters, as signals, as instruments of communication, as extra limbs and tools of many uses. A woolly monkey curls the tip of its tail into a circle, plants this loop on the ground, stiffens the rest of the tail into a supporting column, and has a portable chair! A honey bear, raiding a nest of bees, hangs head downwards and then, when it wants to make its getaway, climbs its own tail. Pangolins, which are scaly anteaters living in west Africa, block their burrow entrances with their armoured tails.

While there are almost as many tail uses as there are animals, there are also some popular notions about animals' tails that aren't true.

For instance, it is said, if you pick up a skunk by the tail, the skunk can't discharge its malodorous spray. Well, it is true that sometimes a skunk, captured by the tail-grabbing technique, fails to release its stench. This may be either because the particular skunk is exceptionally affable (all skunks, by the way, are placid, friendly animals, and don't ordinarily discharge their sulphide unless extremely frightened or harassed!), or it may be because the stench-releasing ability varies from skunk to skunk. The fact to be remembered is that great many skunks can and do function just as effectively when hoisted by their tails as under any other circumstances.

SUDHIR GHATNEKAR

AWARDS & APPOINTMENTS

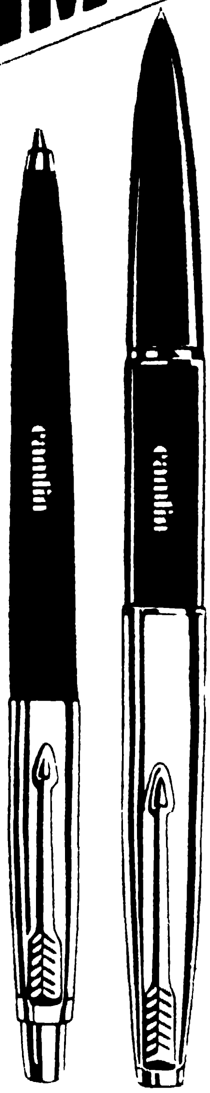
AEC reconstituted

The Atomic Energy Commission has been reconstituted with three new members. The new Commission consists of: Mr. H. N. Sethna (Chairman), Dr. R. Ramanna, Director, Bhabha Atomic Research Centre, Bombay, Dr. Manmohan Singh, Secretary, Department of Economic Affairs, Mr. Mantosh Sondhi, Secretary, Union Ministry of Industry, and Mr. V. Shankar, Secretary to the Prime Minister. The last three are the new members. They come in place of Mr. M. C. Kaul, Mr. P. N. Haksar, and Mr. P. N. Dhar.

Mitra heads NCERT

Dr. S. K. Mitra has been appointed Director of the National Council of Educational Research and Training, New Delhi. Dr. Mitra, who was Joint Director earlier, had been functioning as Director of the Council following the resignation of Dr. Rais Ahmed earlier this year.

STAR PERFORMERS



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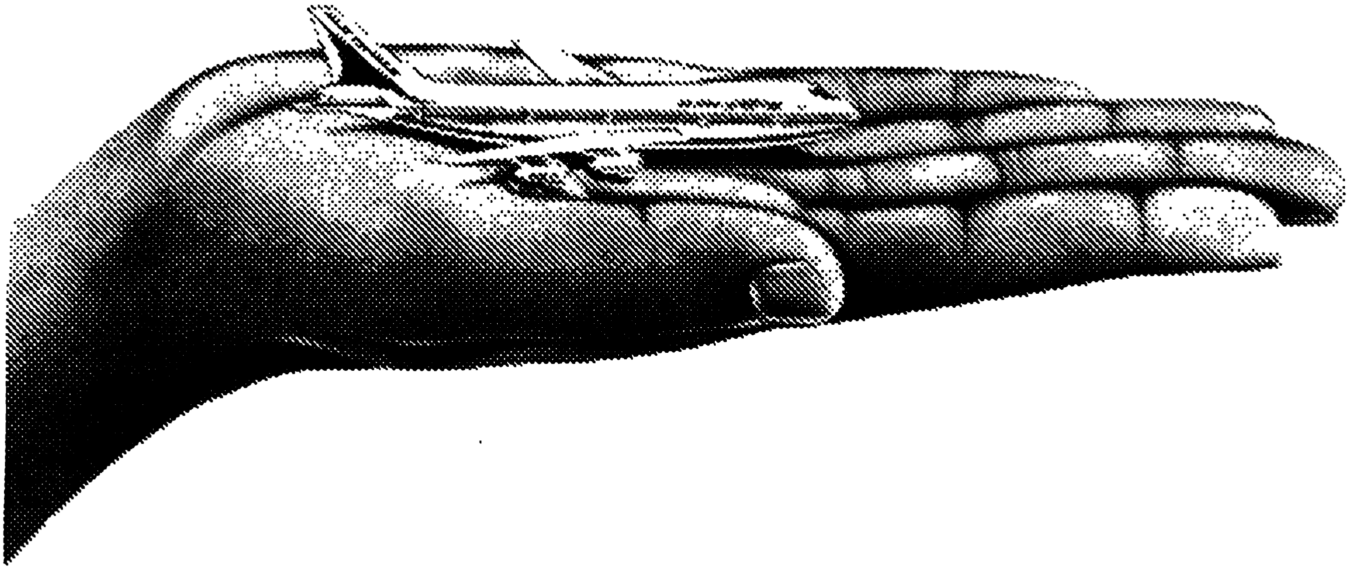

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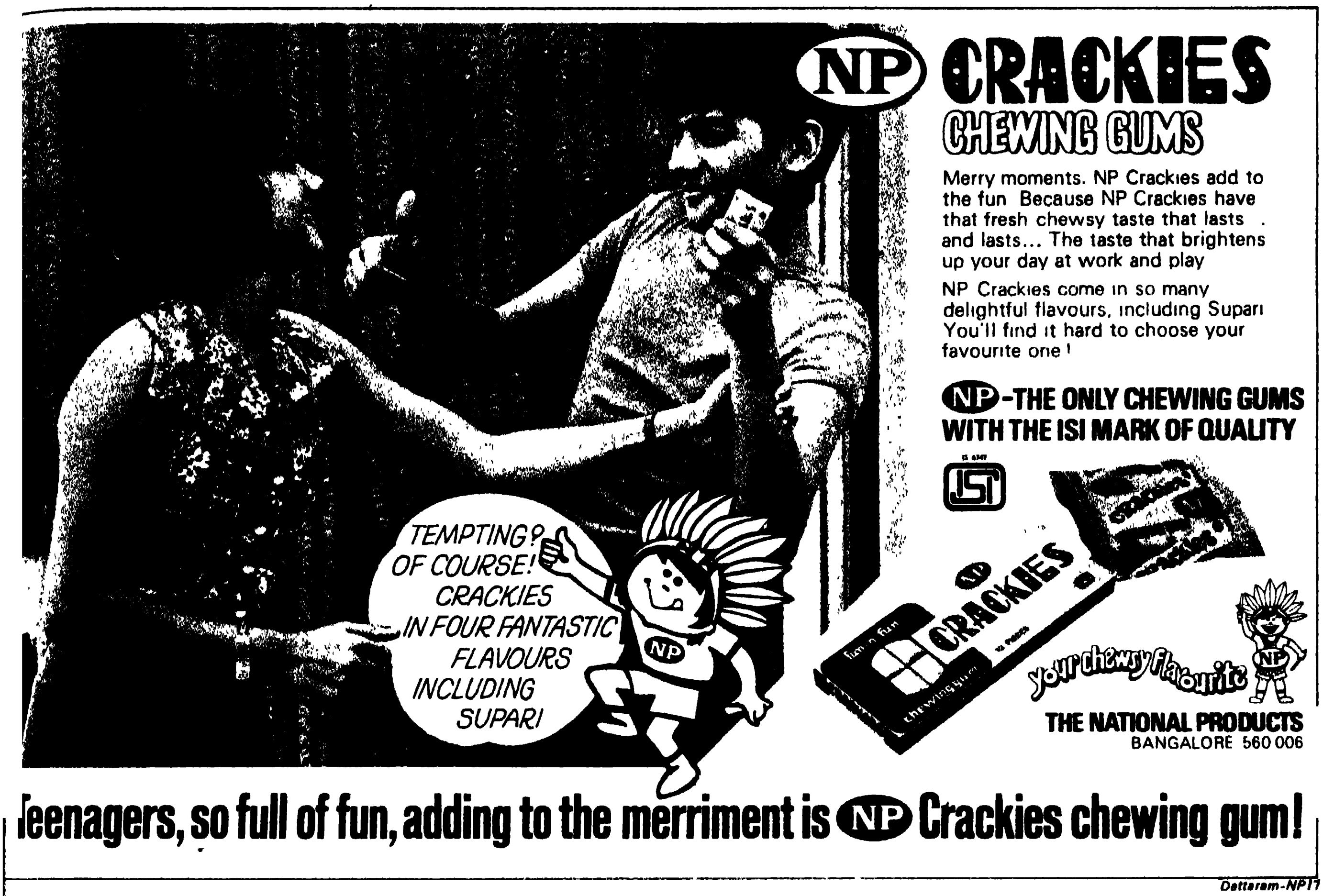
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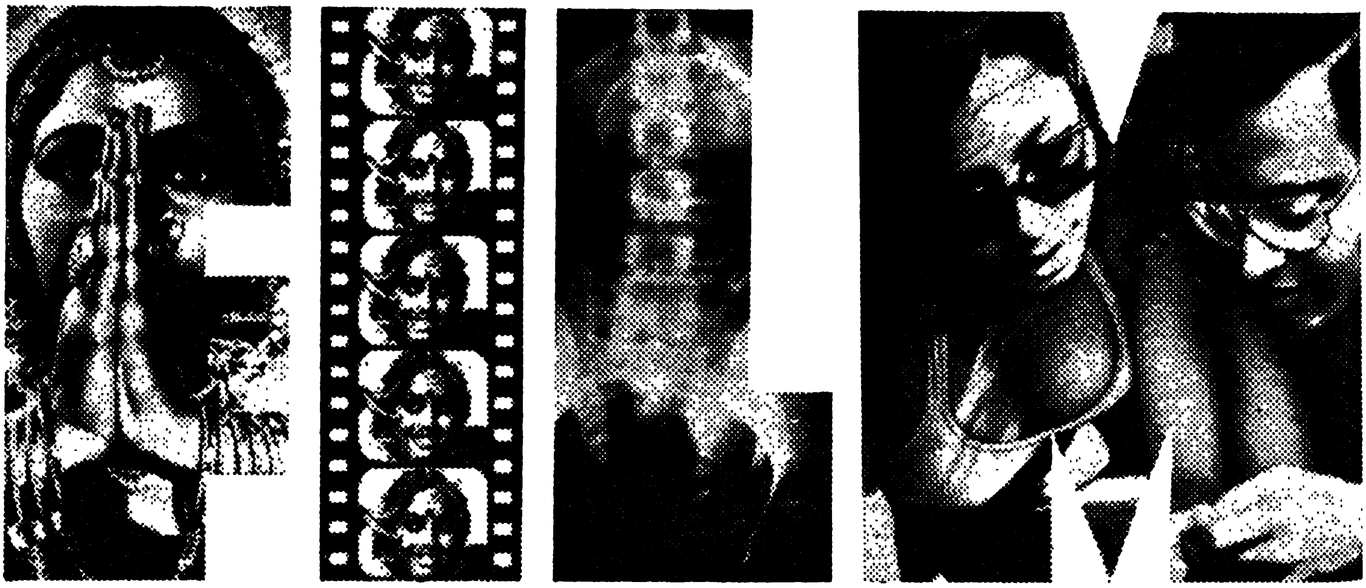

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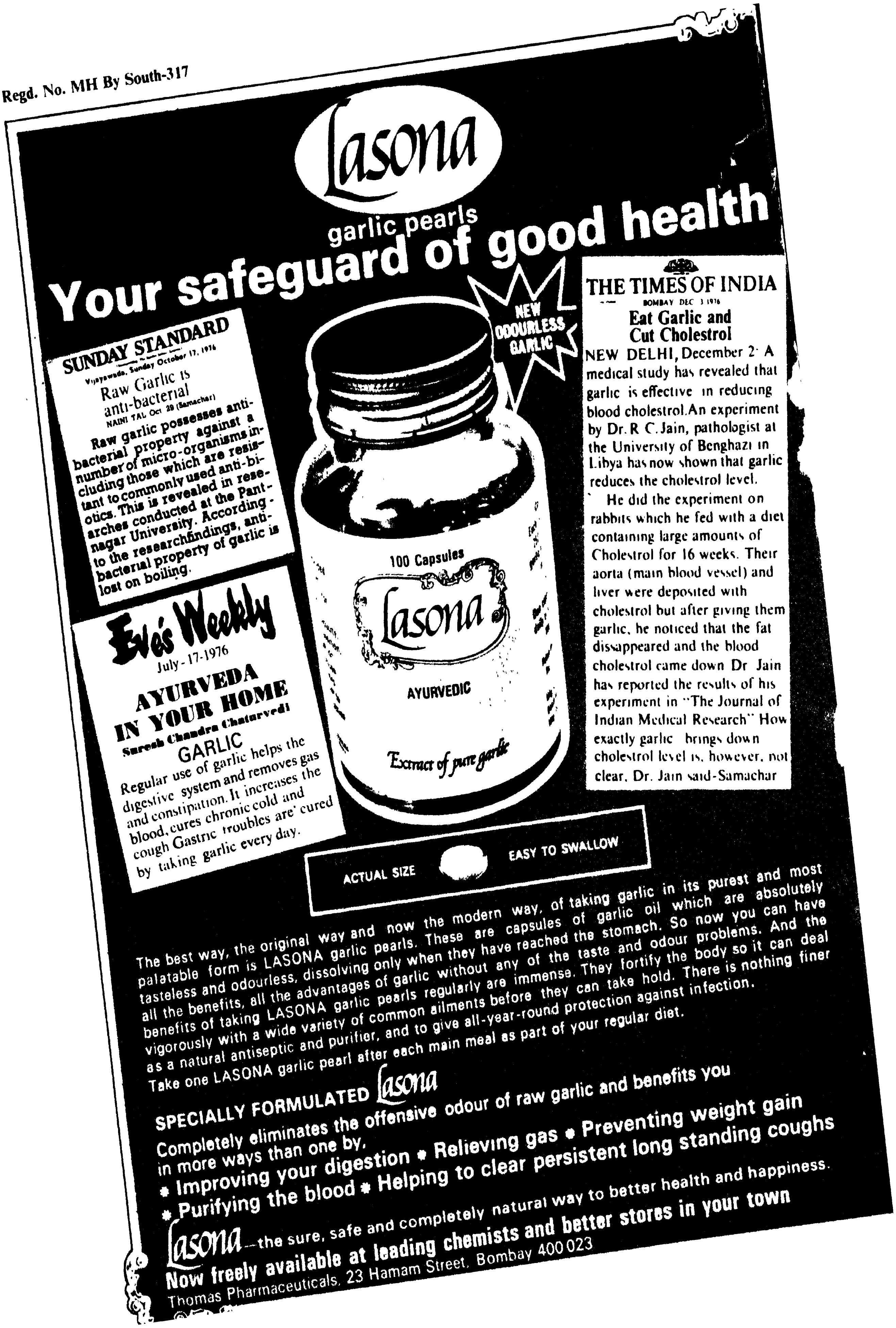
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SUNDAY STANDARD

Vijayawada, Sunday October 17, 1976

Raw Garlic is anti-bacterial

NAINI TAL Oct 29 (Samachar)

Raw garlic possesses anti-bacterial property against a number of micro-organisms including those which are resistant to commonly used anti-biotics. This is revealed in researches conducted at the Pant-nagar University. According to the researchfindings, anti-bacterial property of garlic is lost on boiling.

Eve's Weekly

July-17-1976

AYURVEDA IN YOUR HOME

Suresh Chandra Chaturvedi

GARLIC

Regular use of garlic helps the digestive system and removes gas and constipation. It increases the blood, cures chronic cold and cough Gastric troubles are' cured by taking garlic every day.

THE TIMES OF INDIA

BOMBAY DEC 3 1976

Eat Garlic and Cut Cholestrol

NEW DELHI, December 2 A medical study has revealed that garlic is effective in reducing blood cholestrol. An experiment by Dr. R C. Jain, pathologist at the University of Benghazi in Libya has now shown that garlic reduces the cholestrol level.

He did the experiment on rabbits which he fed with a diet containing large amounts of Cholestrol for 16 weeks. Their aorta (main blood vessel) and liver were deposited with cholestrol but after giving them garlic, he noticed that the fat dissappeared and the blood cholestrol came down Dr Jain has reported the results of his experiment in "The Journal of Indian Medical Research" How exactly garlic brings down cholestrol level is, however, not clear, Dr. Jain said-Samachar

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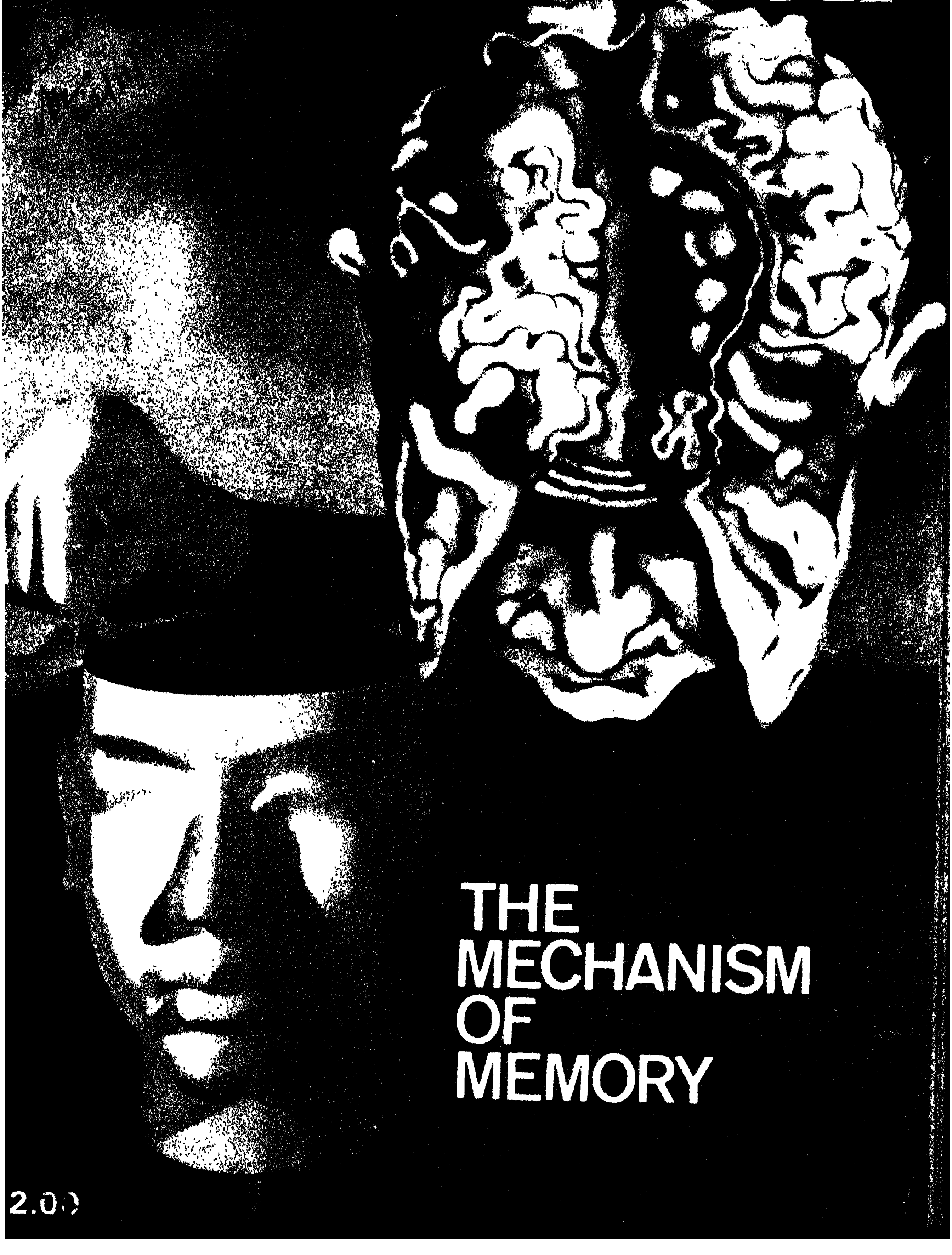
NOVEMBER 1977

CIENCE ODAY



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"Wish we had a 'fridge' like the neighbours!"

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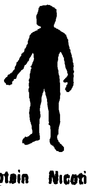

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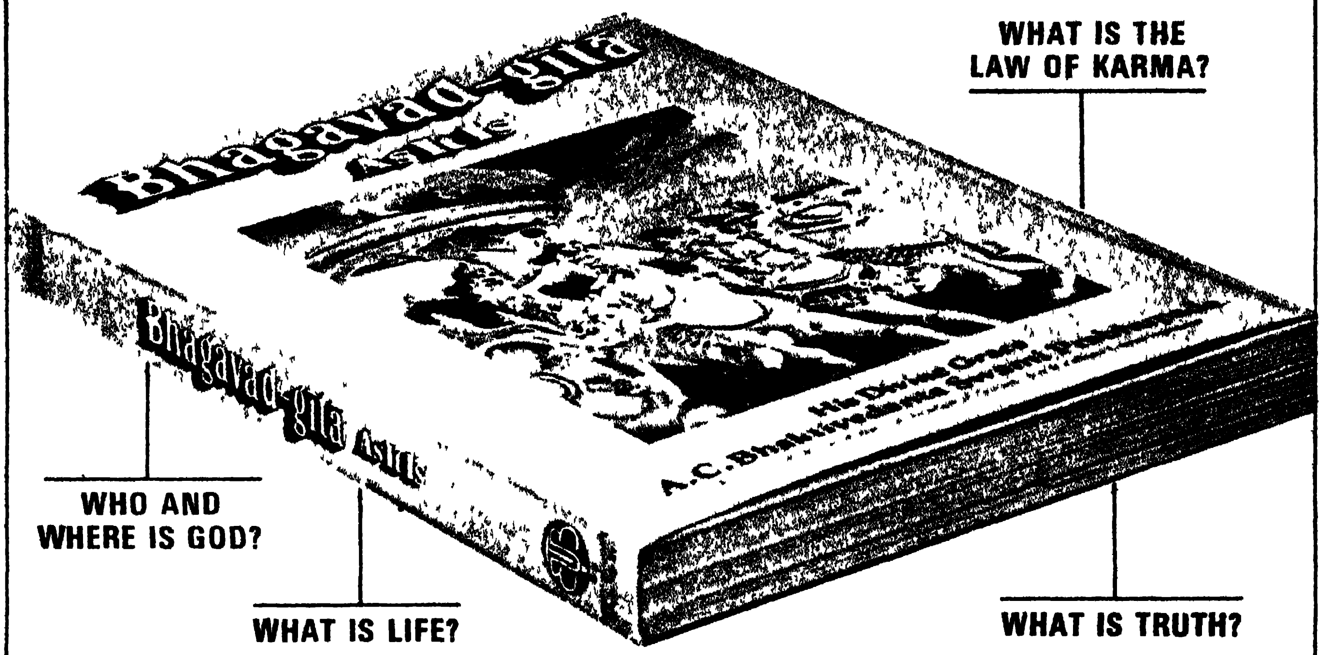
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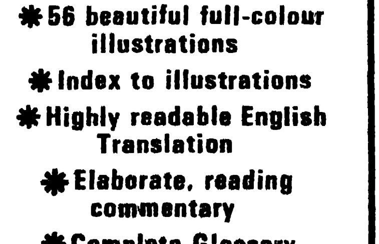

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SCIENCE TODAY

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Can memory be improved as the mail order houses keep promising through the ads? The search for an answer prompted this special group of articles that try to probe the mechanisms of memory — at the biological, behavioural as well as cognitive levels

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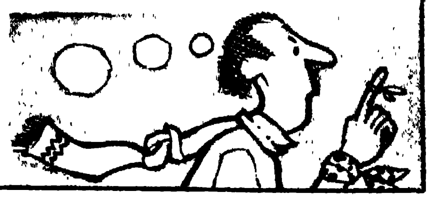

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60 ENTROPY AND THE SOURCE OF BIOLOGICAL ORDER
Vivek Monteiro

Entropy, simply, means 'lack of information' in a system. How does this concept explain biological order in terms of food molecules?

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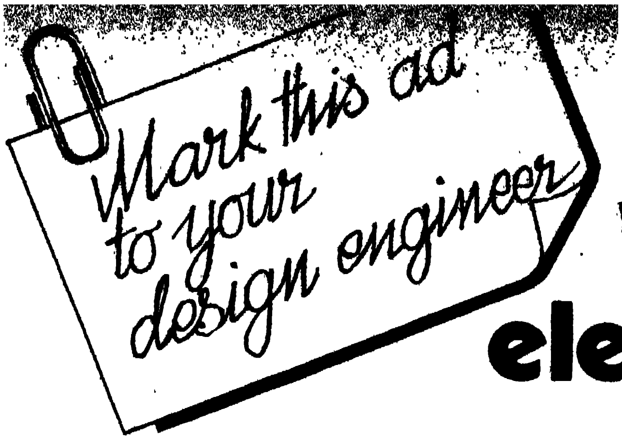
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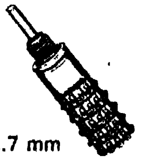
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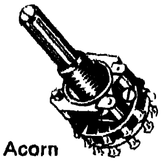
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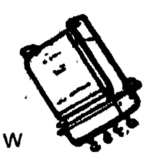
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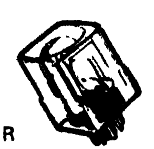
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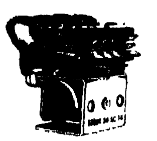
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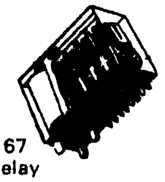
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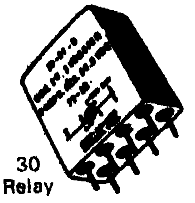
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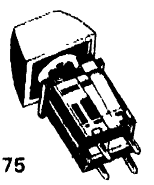
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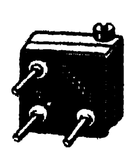
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Academic science and technological culture

In "Academic Science and Technological Culture" (August 1977), Prof. Narasimhan has voiced concern about the continued absence of what he has described as "work ethic" and 'middlemen and has pointed out the urgency of "bridge-building , between academic science and technology. It may be worthwhile to find out if similar catalysts were responsible for the construction of temples, advanced metallurgy as evident in the Iron Pillar near the Qutab Minar in Delhi, sea-faring vessels, etc in India and, if so, how such catalysts vanished.

To effect a speedy bridge-building, may I suggest that (1) every science student should spend half his college tenure in a technological environment and this must be given proper weightage, unlike today s half-hearted practice, (2) the fabricator must invite the academician to spend time in his factory/field/mine and to obtain first-hand information and suggest means of improvement, (3) policy-making bodies in the country should include fabricators with proven ability in their respective fields, and such bodies should not be decorative but must have authority (4) key men from the private sector must be invited to attend deliberations of the public sector industries (5) the academician must make a conscious effort to instil a sense of dignity of manual labour in his students, and (6) fabricators should be induced to adapt one or more academic institutions in their branch of technology

KALYAN K GHOSE
Computer Maintenance Corporation
115, Sarojini Devi Road
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The gap between the thinker scientist" and artisan-technocrat in our society is too wide For the educated class, work-ethics is a sneering term. The dominance of the western imperialist culture for over a century has created a western-educated elitist class of scientists, technocrats, engineers, doctors, etc , they have their elitist language, too On the other side, we have the illiterate or semi-literate but ingenious class of artisans such as carpenters blacksmiths, goldsmiths, masons and weavers — looked down upon as inferior, ignorant and useless by the elitist scientist-technocrats.

What we need is 'middle-men who can bring and interpret 'science to these rural artisans in their own terms and language, this needs the use of vernacular languages, not English. If this is done, the rural people would be quick to translate scientific ideas into their arts. Any culture, including a scientific culture, can grow only from the grassroot level

M. G. TATIYA
Shahada, Dist. Dhule, Maharashtra

Prof. Narasimhan cites the "conscious" organisation of science by the so-called 'bridge-builders' through various institutions and philosophical clubs as one of the most important factors in the development of a technological culture — as if these bridge-builders were committed to doing this for the sake of scientific and technological advance. Invariably, all these bridge-builders either belonged to the ruling class or represented the class interests of the bourgeoisie. The organised scientific activity — the publication of books, lecture demonstrations, academies, philosophical clubs, etc — were financed effectively by private enterprise or by the State, which, in turn, represented the class interests of the capitalists The creation of these institutions also represented the need of the new industrial bourgeoisie to take science into its own hands in order to make it serve their purpose of increasing profits. That is why they acted as a 'brake whenever it came to scientifically examining, and possibly altering, the social system from which they drew their wealth

If a technological culture is lacking in India today, it could similarly be traced to the existing modes of production — mostly feudal in the rural areas and capitalist in the large urban areas So we find our science and technology lacking the necessary impetus the same way as medieval Europe felt it On the contrary, the position enjoyed by science in China and the USSR brings out the dialectical connection between the stage of development of a society and the character of its science One could infer that the solution lies not in creating more institutions to serve the interests of the bourgeoisie but in establishing new socialist relations of production.

V RAGHUNATHAN
28/10, Rajinder Nagar
New Delhi 110 060

Science policy — on the wrong track

The main reason for the slow progress of science in India and its poor impact (New phase in science policy? ' Letters, September 1977) on the rural people is the wrong policy of developing science programmes on western lines And the problem is common in several developing countries In our eagerness to catch up with the West, we have drawn up science and technology plans centred on the ' urban man '. The planners often blame " mass illiteracy ' for the slow dissemination of scientific knowledge in rural areas This is far from the reality. Was it not the uneducated villager of Punjab and Haryana who produced the " green revolution in wheat? The villager will not lag behind in adopting what is best for him and his family. One often talks of modernising the tractor, but rarely thinks of improving the plough used by millions of farmers.

This is where rural people felt isolated from science. Too much sophistication confined to urban areas satisfying the needs of urban dwellers left the villager to think of science as a tool ' intelligently ' used by ' affluent persons ' to satisfy their material needs and boost their ego; he often looks on science with contempt.

What is needed is to correlate Gandhian principles with technology The eminent economist Dr. E F. Schumacher observed ". . . the great paradox of our age is that the Gandhian ideas were implemented not in India but in Red China, not there is no mass production, but production for the masses there s enough for everybody's greed — all these ideas are Maoist but actually they come from Gandhi They had their first enunciation in India and implementation in China — as far as I can see.'

The CSIR took some initiative in adopting districts But there is often a pitfall in such schemes The villagers and scientists will see the problems quite differently, and the projects proposed by the scientists will not necessarily be meaningful to the villagers And if projects are imposed on them, they are likely to be sceptical and may well resist rather than co-operate Rural development schemes, in the broadest sense, require a good sociological approach and as much psychology as scientific knowledge

A JAGADEESH
Convenor
Society of Science for People
2-275, Nawabpet, Nellore 524002
Andhra Pradesh

Is it mere platitude?

After reading the resolution of the Indian National Science Academy (September 1977), I felt pretty dejected. Though, by and large, it has pointed out the bureaucratic infiltration into the scientific community, it is not emphatic enough There is no dearth of examples to expose the activities of the short-sighted and power-hungry bureaucrats and some of the egoistic higher echelons of the scientific community itself But the most irritating are the politicians It is they who should be held responsible for the slow growth of scientific progress in India. People who do not know the distinction between electron and neutron or between virus and bacteria make decisions on how many MW a power station should produce, or in which part of the country geological prospecting should be carried out.

Though, time and again, the glaring truth has been repeated (" ... education which has no relevance to the needs of the country '), nothing has happened. Again, no attempt has been made to improve the social status of a " technical worker . All this has led to frustration and unemployment Why can't a person work as an unskilled or skilled worker after his graduation? Why should a dull and reluctant student go to college only to master the art of dishonesty and lose some valuable years? It has been shown that university education of more than 70 per cent of the students has no bearing on the work they later do. Then why this fanfare about higher education? Surely, I have the choice to become a carpenter, but

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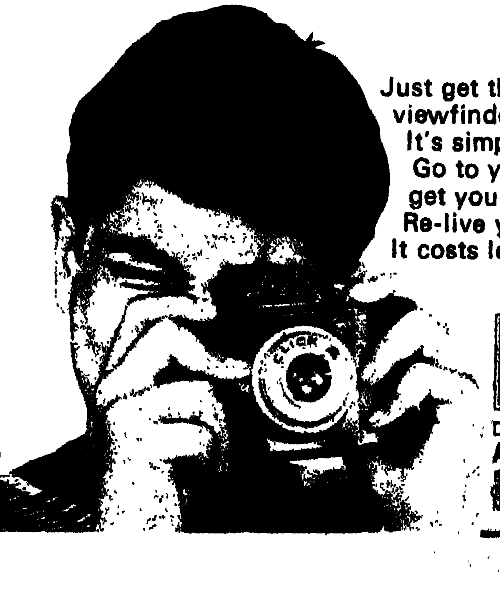

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then my father would become a monk and my mother would shed endless tears and my friends would be scandalised in receiving me. That is the cultural milieu in which we live.

GAUTAM BHATTACHARYYA
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Calcutta 700 026

Dating old trees

D P. Agrawal and Sheela Kusumgar state (" What is radiocarbon clock ? Is it accurate " ? Question & Answer, June 1977) that it was assumed that the intensity of cosmic rays has not changed with time. How can we ascertain this ? If the assumption is wrong, radiocarbon dating will also be incorrect Further, the proportional quantity of nitrogen and CO_2 in the past atmosphere of the Earth could have also changed the formation of ^{14}C and the assimilation of CO_2 by plants If the proportional quantity of nitrogen in the past atmosphere was low, then the small number of N_2 molecules could have been affected by cosmic rays and a low quantity of ^{14}C could have been formed Further, if CO_2 in the past atmosphere was proportionally very high, its assimilation by plants should have been high These three points also greatly affect radiocarbon dating.

M. MOHAMED SHERIFF
44, Middle Street
Singampathu, Kalkad
Tirunelveli Dist, Tamil Nadu

The authors first say that materials of organic origin are dated by the radiocarbon method and the dating starts after the plant or animal dies Later, they mention about dating old trees by this method The carbon dating method relates only to the period after the death of the tree The number of rings gives the age of the tree at the time of its death or, if it is living, at the time of counting How can the two methods be compared ? And since the tree has to be cut for counting the rings, isn t it a destructive method ?

S. K. KASLIWAL
Technical Services Division
Bharat Heavy Electricals Ltd
Bhopal 462 021

Dr Agrawal writes: **If there were significant fluctuations in the cosmic ray flux in the past, they would be reflected in changes in $^{14}C/^{12}C$ ratios, and thus affect ^{14}C dates also Earlier work on cosmic ray intensity in the last one million years has shown that there have been no significant fluctuations (Arnold, Honda & Lal in *Journal of Geophysical Research*, Vol 66, 1961, p. 3,519). But to verify relatively short-term variations in historical times, studies have been made to compare ^{14}C-dated samples with well-dated historical and dendrochronologically-dated samples. The study reveals that there has been some variation in $^{14}C/^{12}C$ ratio in the past 5,000 years, though the exact magnitude has not been agreed upon so far.**

Trees add up a ring every year to their girth. When a new ring is formed, the older one becomes only a mechanical tissue and does not take part in the plant's metabolic activities; thus, for ^{14}C dating, it is a dead ring. But, as suggested by us, some plant nutrients may pass radially through these rings and add younger carbon to them (no metabolism is involved). Dendrochronology can be used only on cut trunks of trees and is, therefore, destructive.

I suggest these two books for further information—*Radiocarbon Dating* by W. F. Libby, Chicago, 1952, and *Radiocarbon: Calibration and Prehistory*, ed. T. Watkins, Edinburgh, 1975

Sweetener for ice candy

This has reference to " A super sweetener (Ideas & Inventions, August 1977) One of the problems faced by the Council of Scientific and Industrial Research-Polytechnology Clinics, set up to identify the problems of industries in different States and to refer them to R & D organisations within or outside the CSIR, is the development of an artificial sweetener to be used in the manufacture of ice candies The product should be an acceptable, stabilised sweetener, conforming to the Food Adulteration Act, 1954 The ice candy should retain its shape for 24 to 28 hours when stored in a push cart with internal temperatures ranging between 20 and 25°C The cost of production of the sweetener should not exceed Rs 30 to Rs 35 per kg The demand for sweetener in Andhra Pradesh alone, where the study was done, is 150 kg/day

I hope either the author, Dr. Malshe, or any of your readers will take up the problem

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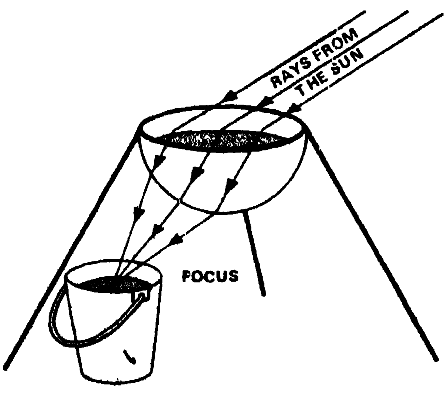
An alternative sun basket

Long before the " Sun basket idea appeared in SCIENCE TODAY (Ideas & Inventions, May 1977), my science teacher had suggested to us a better and cheaper device based on the same principle Cut out a polythene bag into a semi-spherical shape and join the edge to a circular metal ring of the same diameter Fill this polythene basket to the brim with water and suspend it supported on stands. The focus of this half convex lens must lie about 30 cm above the ground at midday. The material to be heated is kept at the focus (see sketch).

This device costs less and its efficiency is higher than that of the sun basket. The disadvantages are that it would be less efficient when the Sun is not overhead, and that part of the water will evaporate. Also, the user must be careful not to burn his hand by placing it at the focus.



S. JAIN
Std. IX, St. Vincent's School
Hill View Park, Asansol, West Bengal

☐ **A similar idea was described in our July 1976 issue (p. 44)—Ed**

The sal seed story

We refer to Mr V Venkappa s letter ' Relevant technology in August Sal seed collection and sal oil production have been discussed in various seminars and forums and our Association wishes to make the following observations

While it is correct that the labour is paid on an average Rs 4 per day for the collection of sal kernels, it is not right to imply it is lower than normal According to our information, it is in keeping with the wages paid to agricultural labourers in areas where sal seed is being collected One should also note that a substantial part of seed collection is done by tribal women and children who are unskilled and who do not necessarily find alternative employment Hindustan Lever were the pioneers in locating a suitable forest contractor and in extending financial help to him to organise sal seed collection

The contractors have to bear a number of other costs, like the cost of decorticating the seeds, packing in gunnies, transportation to railheads, payment of royalties to State Governments (the royalties vary from Rs 100 to Rs 500 per tonne), the cost of transit losses and loss of weight due to moisture evaporation The price that solvent extraction plants can pay the forest contractors in turn, depends on the cost of solvent extraction and the realisation on the sale of sal extractions and sal oil The costs of seed collection and processing have a multiplier effect on the ultimate sal oil cost as the oil percentage is only 13 to 14 Sal oil prices depend, in the short term, only on demand and supply, and bear no relation to the cost of production In the long term, of course, encouraging exports would mean higher prices to the contractors and higher wages to the Adivasis

As far as we are aware, forest contractors do not make windfall profits. Nor do solvent extraction plants processing sal seeds earn significantly higher profits than those processing other oil seeds. Sal oil produced by the solvent extraction plants till recently found a market in soap production Here again, several of our member firms have done pioneering work by further processing sal oil and exporting it.

Sal seed collection was first organised in a small way in 1967-68 when only about 2,000 tonnes were collected. It has now reached 1,50,000 tonnes. This implies that the tribals and Adivasis now get nearly Rs 30 to 35 million in wages, where there was no such earnings before 1967-68.

N. J. AGRAWAL
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SUITING THE WORD TO THE DEED

With a lot of machinery and equipment being exported from one country to another, it is necessary that the manufacturers instructions to the user be couched in as lucid a language as possible to avoid damage to the equipment or to the user Most of us, for example, know how to operate a public telephone, but you would have to be a clever person if you could do it with a new model without any instructions whatsoever. This is all the more true in the case of complicated machinery. Even when the instructions are quite clear, it is generally helpful if simple affirmative sentences are used, introducing the passive or the negative either slows down the user or makes him commit errors

Some years back, the pattern of public telephone booths in Britain was changed In the new boxes, the instructions were worded negatively, for example, 'Do not insert money until number answers The Post Office has now thought it better to replace these with more affirmative instructions, so that the caller is told in correct sequence what he should do rather than what he should not

It is unwise, says D E Broadbent of the Oxford University s Department of Experimental Psychology (UK), in an article published in '*Applied Ergonomics*' (March 1977), for instruction manual writers to write before starting the engine, depress the carburettor plunger instead of after depressing the carburettor plunger, start the engine the latter sentence gives the correct sequence of operations

Yet it may be quite suitable to use a negative when one has to challenge some presupposition of the reader and to use negatives or passives if they match more closely to the order in which the machine will be seen or unpacked

TELEPHONE
COIN IS NOT TO BE INSERTED IF CALLED PARTY DOES NOT ANSWER BUT NOT BEFORE DIALLING

CHOOSING THE SEX OF THE FOETUS

Since the genetic sex of an individual is determined by whether the egg cell is fertilised by an X-bearing sperm or a Y bearing sperm it might be possible to have a child of the desired sex by using sperms of the desired type — if a way could be found to separate the X-bearing and Y-bearing sperms Several claims have been made in the past In 1974 R J Ericsson and his team in Berlin claimed to have developed a method which utilised the differential motility of the sperms to separate them Other workers, however, were not able to confirm the usefulness of the method Now a team from the Institute for Research in Reproduction, Bombay, consisting of Padma R Shastry, Umashashi C Hegde and Shanta S Rao, has in a letter to *Nature* (1 September 1977) reported a method of separating the two types of sperm cells without affecting their viability

A suspension of spermatozoa from semen samples collected from volunteers was treated with a "density gradient' consisting of a mixture of Ficoll-400 and sodium metrizoate, and then centrifuged After centrifugation, the sediment was rich in Y-bearing sperms, while the interface consisted mostly of X-sperms The percentage of Y-bearing sperms was found to be 76 9 per cent compared to 44 4 per cent before separation The motility of and viability of the sperms was slightly reduced but this is attributed to centrifugation, and not to the density gradient

TYPING WITHOUT THE TOUCH SYSTEM

Professional typists are taught to type blind, that is, without so much as taking a peek at the typewriter keys Now the prototype of what may well turn out to be a new breed of typewriters makes it imperative on the part of the typist to see what he types

A post-graduate student at the University of Toronto s engineering department has developed a device which allows the typist to rattle off about 60 characters a a minute without actually touching the keys

The principle behind it is fairly simple A small screen which contains all the letters of the alphabet and some numerals plus an optical tracking mechanism and control circuits, is mounted on an ordinary spectacle frame. When the eye rests on any character for one second, the digital controls instruct an electronic typewriter to pound out that particular character

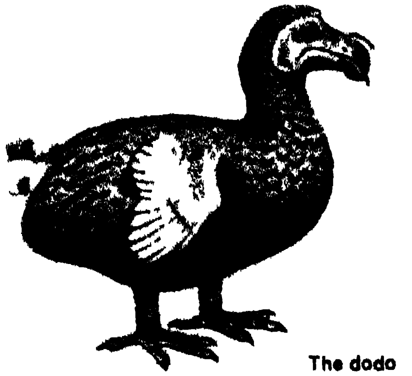
The device will be especially useful to those who have lost the use of their hands, to paralysed people or those suffering from diseases like cerebral palsy. The entire contraption is portable and can be set up in under a minute It has been claimed that a commercial version, using standard components, can be produced for around $500 (Rs 3,760 approx) which is comparable to the price tags on some Indian typewriters in the market

A TREE THAT NEARLY DIED OUT WITH THE DODO

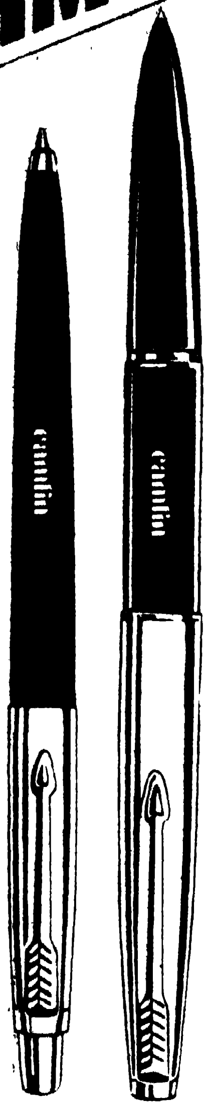
The dodo, as every schoolboy knows, is dead and gone But did its exit nearly kill something else too? Stanley A Temple, an ecologist of the University of Wisconsin (USA), thinks it did (*Science*, 26 August 1977). He believes that the disappearance of the dodo at about the end of the 17th century from the Indian Ocean island of Mauritius has left the tree, *Calvaria major*, in the lurch The tree, once common in Mauritius, is now down to about a dozen old surviving specimens

Calvaria s stony fruits were an important source of food to the flightless bird During its passage through the digestive tract of the dodo, the hard seed-coats were crushed by the stones in the dodo s gizzard, and in the course of evolution the seed wall became very thick to protect its embryo from damage when the dodo swallowed it According to Temple, the seed wall has over the years become so thick that it does not allow the germinating embryo to emerge through it unless the seed wall has first been battered by an external agency such as the stones in the dodo s gizzard Hence the decline of the tree

However, calculations of the probable effects of a dodo s gizzard on the seeds showed that the hard seed coats would not have been totally demolished Temple, who was undaunted by this piece of information, forced *Calvaria* seeds down the throats of turkeys The gizzards of these birds are similar to a dodo s in that they, too, have gizzard stones for crushing food Three of the seeds germinated Temple says, these could have been the first *Calvaria* seeds to have sprouted since the dodo became extinct, some 300 years ago.



The dodo



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RADICAL

BRAIN GAIN

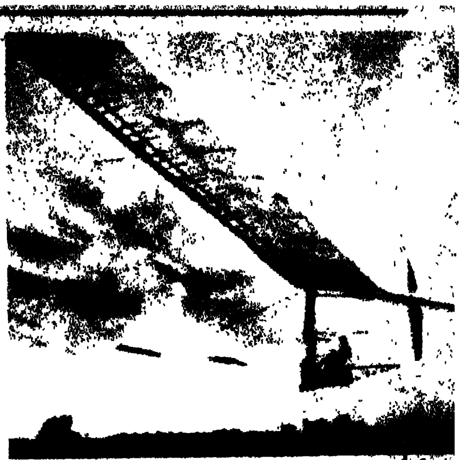
The human brain has over the years gained weight. In a survey of brain weights from 1860 to 1940 it was found that the male human brain registered an increased average weight from 1,372 grammes to 1,424 grammes, while the female brain showed an increase in weight from 1,242 to 1,265 grammes.

Prof. J. A. N. Corsellis of the Department of Neuropathology at the Institute of Psychiatry in London and Dr. A. K. H. Miller of the Department of Neuropathology at Runwell hospital in Essex (UK), who together conducted the study, point out that between 1860 and 1900 the brain weight of women remained static. This 'dark age' is reflected in the lower overall rate of increase during this period in the brain weight of women. However, since 1900, women's brains showed an average annual increase of 0·62 grammes, which is only slightly less than the corresponding figure for males, 0·66 grammes a year.

Prof. Corsellis sums up his study as demonstrating a real increase in human brain weight. "Since weight and volume are known to be closely related, then (brain) size must also have gone up." But what the study failed to indicate — probably being outside its scope — was whether the increased weight has led to a corresponding increase in intelligence.

FLYING BICYCLE

Flying 40 metres under your muscle power seems to be more satisfying than flying 4,000 km in a supersonic transport. That seems to be the chief motivation of people who keep designing flying machines. The latest is Bryan Allen who last August pedalled his "Gossamer Condor" in California in a muscle-powered flight that lasted 7 minutes 28 seconds. The craft has a 21-metre propeller rotating at 96 to 108 rpm, which gives the craft a maximum speed of 19-20 kmph. The propeller is connected to bicycle-like pedals through a system of gears. The mylar-covered wing used piano wires for bracing and cardboard for its leading edge. According to Allen, with the addition of a 1·5 to 2 HP engine, the craft should be able to fly over the countryside on 27 litres of petrol.



CIGARETTES AND HEART DISEASE

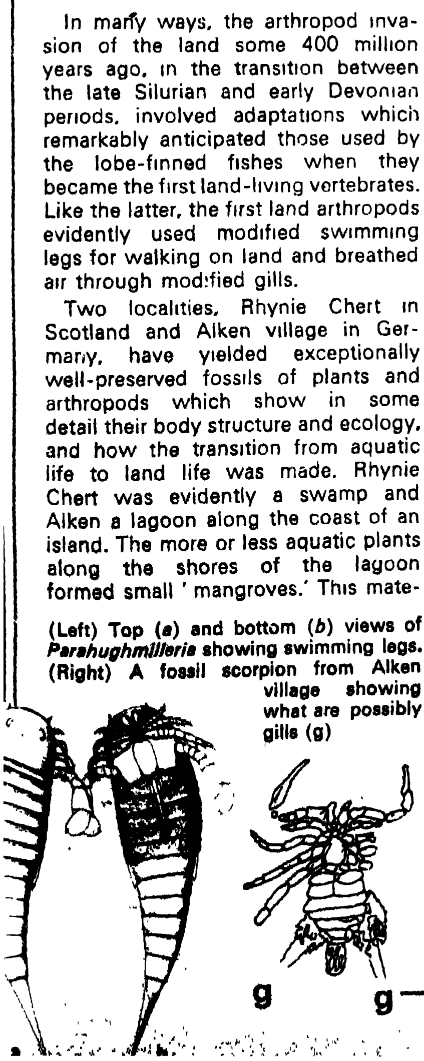
The relationship between cigarette smoking and heart disease, especially arteriosclerosis (a hardening and thickening of arteries), has been based mostly on statistical evidence. Little was known about the physico-chemical mechanism. Now a clue has come from two Cornell University (USA) researchers, Carl. G. Baker and Theodore Dubin, who claim to have isolated a small protein, rutin, that may act as a catalyst in the scarring and occlusion of arteries. Rutin, they say (in a report in the *Journal of Experimental Medicine*), triggers the body's blood-clotting mechanism.

The researchers found rutin in both tobacco and cigarette smoke. How the blood-clotting triggered by rutin may affect artery walls and heart muscles is not precisely known, but the speculation is that, clotted blood can adhere to artery and heart walls and form a matrix for connective tissue cells to grow on, which might lead to a blockage of vascular passage ways.

ARTHROPOD CONQUEST OF THE LAND

In many ways, the arthropod invasion of the land some 400 million years ago, in the transition between the late Silurian and early Devonian periods, involved adaptations which remarkably anticipated those used by the lobe-finned fishes when they became the first land-living vertebrates. Like the latter, the first land arthropods evidently used modified swimming legs for walking on land and breathed air through modified gills.

Two localities, Rhynie Chert in Scotland and Alken village in Germany, have yielded exceptionally well-preserved fossils of plants and arthropods which show in some detail their body structure and ecology, and how the transition from aquatic life to land life was made. Rhynie Chert was evidently a swamp and Alken a lagoon along the coast of an island. The more or less aquatic plants along the shores of the lagoon formed small 'mangroves.' This material and the wet plant debris on the beaches evidently constituted conditions very favourable for an invasion and gradual adaptation to life on land.



(Left) Top (*a*) and bottom (*b*) views of *Parahughmilleria* showing swimming legs. (Right) A fossil scorpion from Alken village showing what are possibly gills (g)

One of the species, a eurypterid (eurypterids are considered to be the ancestors of the modern scorpions) called *Parahughmilleria* was probably able to travel outside the lagoon, with the aid of its swimming legs. Air-breathing in these creatures might have been primarily possible because the gills were protected from drying by the plate-shaped abdominal appendages. At least some eurypterids might have had both gills and spongy masses called pseudotracheae (primitive respiratory structures found in certain arthropods). There are also fossil trails of eurypterids. Hence, most eurypterids were probably able to walk and stay on land to some extent. The pseudotracheae might be regarded as an adaptation that made possible survival during dry periods and during the desiccation of lagoons, estuaries and lakes. A similar adaptation is found in the fossil fishes which gave rise to the first land vertebrates.

The Alken fossils include a fossil scorpion, *Waeringscorpio hefteri*, which possibly had "book gills" instead of the "book lungs" of modern scorpions: hence it was probably aquatic, like most early scorpions.

The report on the fossils, by Leif Størmer of the Institute of Geology, Oslo (Norway), is published in the 30 September 1977 issue of *Science*.

PESTICIDE FROM PEPPER

Black pepper (*Piper nigrum* Linn.) long used by man as a condiment, may prove useful to protect stored food products from at least two pests.

Helen C. F. Su, in studies at the Stored Products Insects Research and Development Laboratory, USA, found that ground black pepper and its alcohol extract are highly toxic to both the rice weevil, *Sitophilus oryzae* (L.) and cowpea weevil, *Callosobruchus maculatus* (F.). Treatments with ground black pepper and the extract were generally toxic to rice weevils even at the lowest dosage of 625 pp/m on soft winter wheat.

When applied topically, the crude and purified black pepper extracts caused very high mortality. However, mortality was much lower among insects treated with piperine, the major component of black pepper, indicating a minor component may play the bigger role, according to Dr. Su, in an article in *Agricultural Research*, June 1977. Dr. Su believes that black pepper should be a safe source of naturally occurring insecticides.

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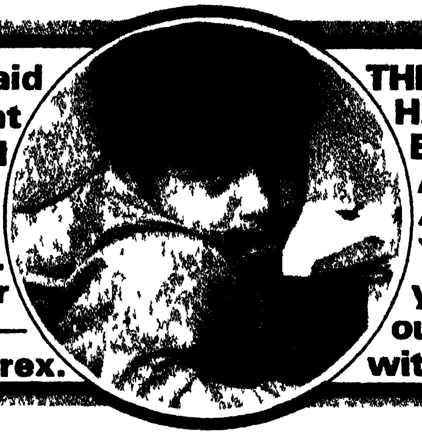

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HEADSTART

How would you describe it? Is it like a gramophone record that can be played again and again on demand? Or is it like photographs in an album, some clear, some fading with time? Is it something one person has more of than another? Can it be improved as most of us would want it to?

It was, to be honest, the last-mentioned aspect that was the germinal idea when this special issue on memory was planned Some of our readers had written despairingly about how they had failed to benefit from rather expensive 'memory improvement courses' Were they victims of fraud? After all, there are such things as mnemonic devices, some dating 2,000 years back to the Greeks

In order to answer if memory can be improved, we have necessarily to begin with a number of other more basic questions What is the mechanism of memory? If it is biological, which it must be since the brain is involved, where is it localised? What sort of modifications go on in the neural network that determine the nature and duration of retention? And how are these related to our cognitive behaviour? The three principal articles in this special section deal with these

The first article is an exhaustive survey of much that has been investigated in the biological area The second article looks into language behaviour in relation to memory The third article looks at models of memory that psychologists have built in trying to answer questions on memory-related processes

These three articles pose more questions than they answer In the face of these gaping inadequacies in our knowledge about memory, it would be beyond our ken to attempt any technical evaluation of the so-called memory improvement techniques; all we have done in the concluding article is to describe some of these devices as they are used by mnemonists The reader may be tempted to try them out. But with the reservation that, the 'memory' mnemonists talk about is not exactly all that biologists and psychologists have in mind.

The Biological Mechanism of Memory

OBAID SIDDIQI

Interest in human memory must be very old. The advantages of a good memory have been prized in all cultures that knew the value of learning. The teachers must have always enjoined upon their pupils "to remember and not to forget". Marcus Fabus Quintillian (AD 35–95), in a manual on the training of public speakers, prescribes three simple rules that govern the operations of memory:

First : attend closely
Second: practise
Third : if you hear anything new, associate it with what you know.

These, however, are practical matters. The philosophic beliefs of the ancient and medieval thinkers on the matter of memory are scattered and fragmentary. Plato had this to say: "I would have you imagine then that there exists in the mind of a man a block of wax, which is of different size in different men, harder, moister, and having more or less purity in one than in another.

"Let us say that this tablet is a gift of memory, the mother of the Muses; and that when we wish to remember anything which we have heard or thought in our own minds, we hold the wax to the perceptions and thoughts, and in that material receive the impression of them as from the seal of a ring; and that we remember and know what is imprinted as long as the image lasts, but when the image is effaced or cannot be taken, then we forget and do not know."

The idea that memory (*smrti*) is made of impressions (*samskara*) left by objects of perception on the mind recurs in the writings of several Indian philosophers. Patanjali lists memory as one of the five modes of mind, the other four being, right knowledge, wrong knowledge, fancy and sleep.

If memory was a block of soft wax in the mind, where was the mind? Although the Greek physician Galen

Fig 1 The two hemispheres of the human brain depicted in a 7th century book on anatomy, *De Humani Corporis Fabrica*, by Vesalius

(AD 130–200) had an idea that the mind might be in the head, Aristotle definitely had it in the heart and thought that the brain was merely a refrigeration device meant to keep the heart cool. Aristotle wrote a treatise *De Memoria et Reminiscentia* and his views on the subject seem to have prevailed until the 16th century. St. Augustine, the brilliant Christian scholar 700 years after Aristotle, thought much about memory. To him memory and time were closely connected and this led him to a deeply personal view of both:

"The past is memory, the future expectation, the present attention. Or more precisely, since the present is the only one which exists, it follows that the present contains within it the past as present memory and the future as present expectation."

Leaving high philosophy aside let us turn to the question, when did scientific investigations of memory first begin? Sir Francis Galton (1822–1911) was a cousin of Charles Darwin. The impressive list of his professional preoccupations included medicine, exploration, meteorology, anthropology and the science of heredity. He also had a more than casual interest in how people remember things, in particular their mental imagery. Galton circulated a letter to a large number of his friends and acquaintances among scientists and scholars asking them to write down, as fully and clearly as they could, recollections of their breakfast table that particular morning. A close study of this material led Galton to make some highly original observations which are set out in a book, *Inquiries into Human Faculty*, published in 1883. This is probably the earliest example of the use of introspective reporting in the study of memory.

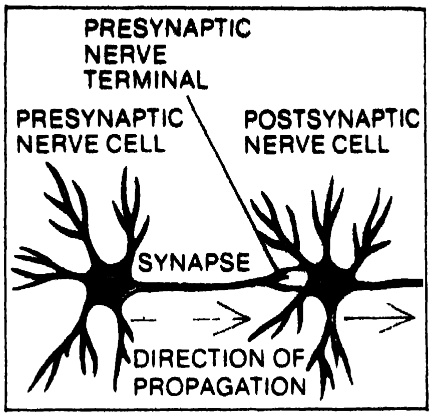
Hermann Ebbinghaus (1850–1909), German physician and psychologist, was a contemporary of Galton. He memorised random sequences of nonsense syllables and examined how long it took to learn such a sequence when forgotten with lapse of time. Ebbinghaus was the first to introduce a successful quantitative measure of retention, that is, time taken to relearn. All of Ebbinghaus's experiments were carried out with a single subject, himself. His results were published in a book, *Psychologie des Gedachtniss*, in 1885. The most impressive thing about these results is the fact that nearly every one of the conclusions reached by Ebbinghaus has stood the test of time and rigorous experimentation.

The researches of Galton and Ebbinghaus stimulated much interest in a quantitative study of learning and memory and mark the beginning of modern experimental psychology. Physical scientists are sometimes apt to turn their noses up at psychology and dismiss it as soft science. So far as our present-day knowledge of human memory goes, they could not be more in the wrong. Studying memory from without, experimental psychologists have found much about it that is interesting. [See the article by Dr. Ramani (pp. 34–40)] Psychological theories of memory are, however, of necessity phenomenological. When it comes to the anatomy and physiology of memory, we seem to know a great deal less. In this article I will try to tell you how much, or for that matter how little, we understand the biological mechanisms that subserve memory.

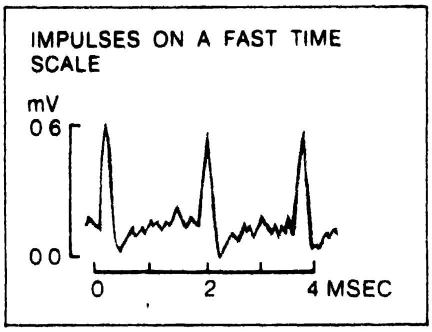
Memory is not an object or a " thing " like our little finger. It is an aspect of behaviour, something that we do. We read a poem or listen to a piece of music Months, perhaps years later, in quite different circumstances, the lines of the verse or the notes of the melody come back to us. A dog is kicked by a policeman; the next time he sees this venerable guardian of the law approach, the poor beast slinks away. In either case, we infer that the past experience was remembered. Memory lies between learning and recalling. The study of memory is thus inseparably connected with these two other activities. One might think of memory itself as made up of three phases: an initial phase in which some experience or activity occurs in the brain, a final phase in which the activity of the brain is clearly influenced by the initial phase, and an intervening phase in which changes that happen in the initial phase persist through time.

Psychologists use the term *engram* or *memory trace* for the retaining phase, a somewhat inappropriate choice of words because it is likely to conjure, in the mind of the reader, the image of engravings upon a gramophone record, somewhat like the Platonic wax. We do not yet know much about the physiological basis of retaining but there is no reason to doubt that

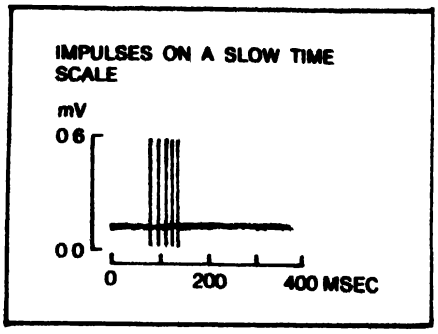
Fig. 2 NEURONS AND THEIR ACTIVITY



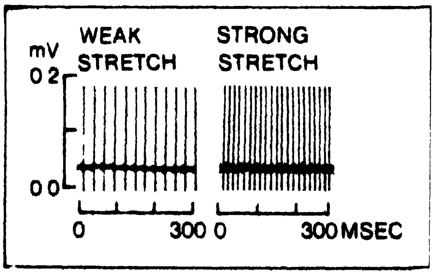
A The axons of nerve cells make connections with dendrites of other neurons Nerve impulses travel along axons



B The "all or none" impulse in a nerve fibre is fixed in size. Different impulses are indistinguishable



C On a slow time-scale, each nerve impulse appears as a spike



D. The firing rate of nerve cells is proportional to the stimulus they receive retaining is achieved by modifications in the cells of the brain. What might these modifications be? Where do they happen? What are the underlying molecular mechanisms? Whether or not we can give satisfactory answers to these questions now, the questions touch upon matters which are interesting in themselves.

In contemplating our own memories we are acutely aware of the vividness of recollection. We recall not just sequences of nonsense syllables, numerical arrays or geometric forms. We also recall with warmth, pleasure, pain or anger. Memories, for us, are coloured with emotions. Inevitably, therefore, we are led to look upon memory as a reflection of our consciousness or self-awareness. Psychologists dealing with memory, not by introspection but with the help of experiments on people and animals, discovered very early that their observations could be analysed and understood just as well if they left " consciousness " completely out of their interpretations. This is not to assert that the admirable quality of self-awareness in our brains plays no part in our memories but simply to point out that so far as experiments go, the contribution of consciousness to the working of our memory has remained undetected. It must indeed be small and it is surprising how far we can go in thinking about memory from a purely mechanistic point of view.

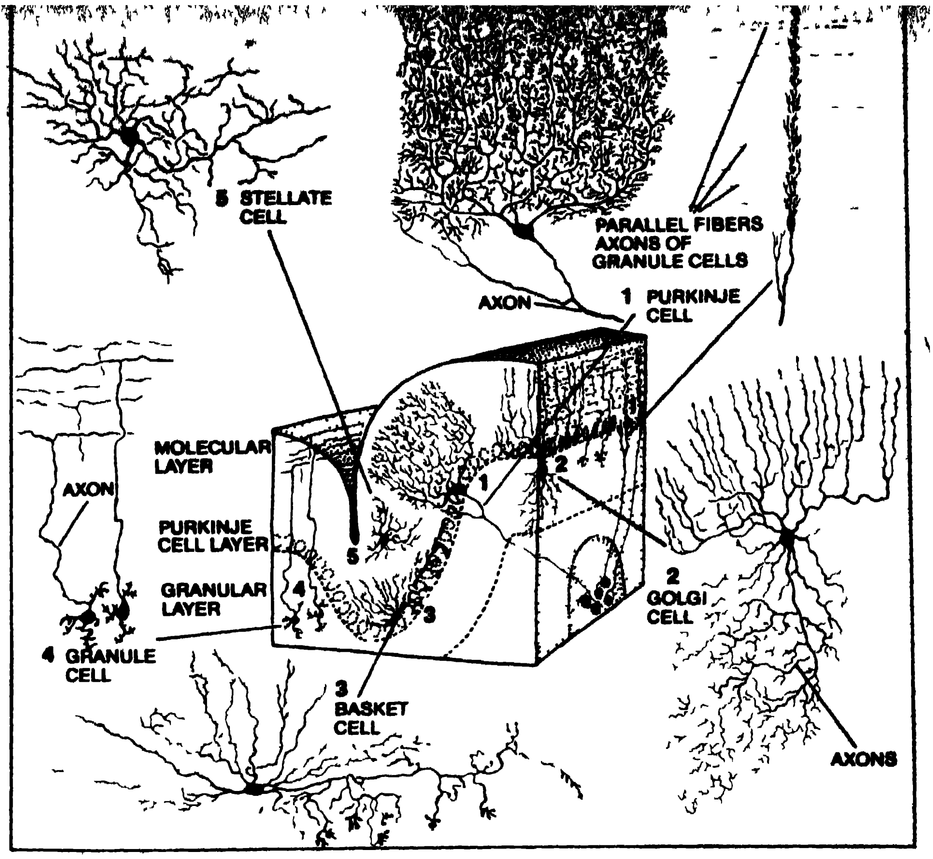


Fig 3 The brain is an orderly structure Billions of neurons in the cerebellum consist of five distinct types whose input-output connections are precisely defined The central portion shows the three-dimensional arrangement of cells in a small part of the cerebellum

Nerve cell and its activity

In order to talk about how the brain might *store memory*, we need to know something about nerve cells and their activity. Let us begin by taking a look at these cells. The nerve cells or neurons vary greatly in size and shape but all of them have a cell-body or trunk that gives out branches. The neuron has the appearance of a tree (Fig. 2A). Electrical signals travel along its cable-like branches. There are two type of branches. *Dendrites* are processes along which incoming electrical signals reach the cell-body. The signals generated in the cell-body travel outwards to other neurons along branches called *axons* or nerve fibres. The axons are the output cables of the nerve cell; these could be extremely long as, for instance, the axons of a sensory cell in the tail of a camel. A neuron can, therefore, be connected to other neurons far away.

At the end, the axon makes contact with the dendrites of the next neuron in the circuit. The junctions are called *synapses* (see Fig. 5A). At the synapse, the ending of the axon is in close association with the membrane of the receiving dendrite. We shall have more to say about synapses later.

Neurons connected to other neurons form neural circuits or networks. These circuits are not just randomly connected groups of cells. The human cerebellum, for example, has about 10,000,000,000 (ten billion) cells. These cells are of five distinct types, each occupying a particular region of the cerebellum and connected in a prescribed manner to other neuronal types (Fig. 3). One of the principal aims of neurobiologists is to discover the relationship between neuronal structure and function (at least they keep trying!). In some instances, they have met with success in this direction, as, for example, in understanding the processing of visual information by neurons of the eye and the visual cortex. There are strong reasons to suspect that the overall pattern of neuronal organisation and most of its connectivity (but perhaps not all) is controlled by the genes of the animal.

The nerve cells conduct their business by means of electrical signals. During the past two decades, we have come to understand a great deal about the biophysics of the signalling process. When a neuron is stimulated, it responds by undergoing a characteristic electrochemical disturbance in its membrane, causing a transient local change in electric potential across the membrane. The membrane potential rises rapidly by about a tenth of a volt and then goes back to its original state, the entire process taking no more than a millisecond or two (1 millisecond = one-thousandth of a second). The cell is said to have fired an action potential. The action potentials can be visualised by placing electrodes either close to the surface of the neuron or inside it and connecting these to sensitive amplifiers and voltage recording devices (Fig 4). In a graphic record, the rapid change in voltage appears as a ' spike ' which is the other commonly used name for action potential.

The action potential in one segment of the axon excites the neighbouring segment causing it to fire; this in turn excites the next neighbouring segment. The signal thus travels from segment to segment till it reaches the end of the axon. The nerve signals are not electric currents passively flowing along a conducting cable What passes along the axon is an electrochemical disturbance that successively invades each segment of the axon; at each point the signal is regenerated anew and has the same amplitude and form. The action potential is, thus, a stereotyped ' all-or-none ' event (Fig. 2B). A neuron can increase or decrease its firing rate in response to the stimulus it receives but each individual signal remains the same as

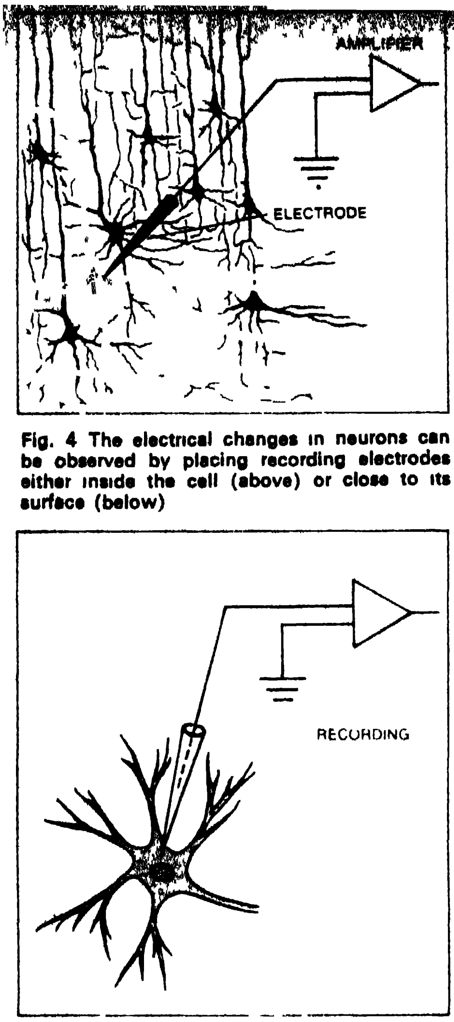


Fig. 4 The electrical changes in neurons can be observed by placing recording electrodes either inside the cell (above) or close to its surface (below)

every other signal. As the action potentials are distributed randomly over time, the signalling patterns of individual neurons, whose firing frequencies lie in a given range, are largely indistinguishable. As Sherrington clearly saw 50 years ago, the signals carried by a particular neuron derive their significance not from the pattern of signalling but from the connections the neuron makes with other neurons. The only possible exceptions to this rule might be neurons that generate periodic or phasic signals. The fact that most neurons fire in, more or less, the same way is an important point sometimes neglected by theories of memory that postulate translation of electrical signals into chemical structures. [See the section "Biochemistry of Memory", p. 26.]

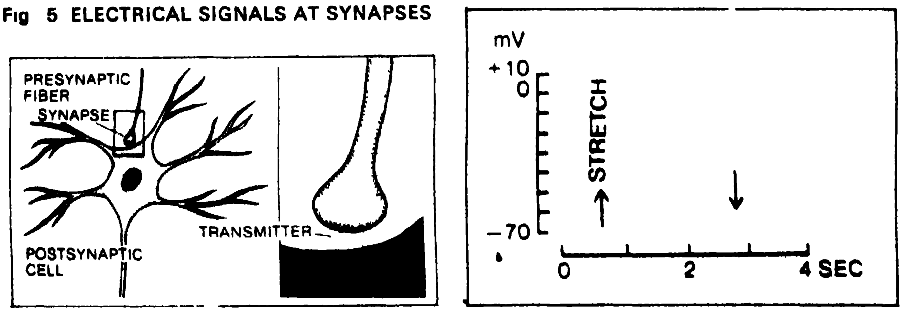
When the action potential reaches the end of an axon it encounters the synapse. The presynaptic part of the junction is a highly specialised structure packed with a chemical substance called the neurotransmitter (Fig. 5). Nerve signals at the end of the axon change its electrical potential and as the tip of the axon is depolarised, it releases the chemical transmitter in measured amounts proportional to the frequency of firing. The transmitter acts on the post-synaptic membrane and causes a potential change in the signal-receiving neuron. There are different types of synaptic junctions, each employing a characteristic transmitter. Some synapses are called electrical because the membranes of the two cells are electrically coupled and the depolarisation in the presynaptic ending spreads across the junction without the mediation of chemical transmitters. Synapses, both chemical and electrical, mark the ending of all-or-none transmission of signals. At this point the firing frequency is converted into an electric potential, passively spreading into the postsynaptic cell. This brings us to the second type of electrical signals with which neurons deal; although less well understood at present, these are far more important for our purposes than the all-or-none action potentials.

The synaptic potentials in the dendrites of the receiving neurons have three important properties. First, each synaptic signal has a characteristic sign; the potential may rise (depolarise) or fall (hyperpolarise). The synapses which cause depolarisation are excitatory (+), those which cause hyperpolarisation are inhibitory(—). Second, unlike the all-or-none firing in the axon the synaptic potentials are graded; the signal can have any value within a prescribed range depending upon the discharge in the presynaptic axon Third, the synaptic potentials spread passively from the point of their origin, decaying in amplitude in a complex way which depends upon the exact size, shape and material structure of the neuron.

Imagine yourself sitting in a neuron at the place where its axon originates. This place, incidentally, is called axon hillock. You are receiving synaptic signals from other cells through hundreds, perhaps thousands, of synapses, each contributing a certain amount of 'increase' or 'decrease' in potential. All that you note at the hillock is the sum total of these changes. This is clearly not a simple sum. Some of the synapses contribute a great deal, either because they produce large signals or because they might be situated close by. Others may contribute little, because, for instance, they might be located at the far end of the thinnest dendrites. When the summed potential at the axon hillock exceeds a certain threshold, the axon will produce a burst of spikes which will travel to the next synapse.

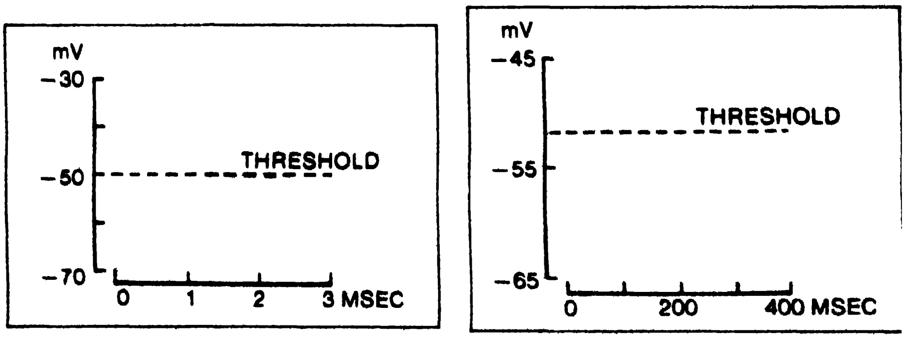
What we have here is a 'summing amplifier' which integrates the incoming signals according to a prescribed set of rules A neuron is not just an element of the neural circuit. It is a highly sophisticated device, capable of a great deal of information processing. The output characteristics of this device are governed by a forbiddingly complicated set of variables. *Any lasting change in these characteristics constitutes a potential mechanism of memory*

Fig 5 ELECTRICAL SIGNALS AT SYNAPSES



A The junctions between neurons are called synapses At most synapses the presynaptic terminal liberates a chemical transmitter

C. Adequate depolarisation leads to firing of action potentials



B At excitatory synapses, the transmitter acts on the post-synaptic cell to depolarise it towards its firing threshold

D. At inhibitory synapses, the transmitter acts to change the membrane potential away from the threshold and inhibits firing

Very little is, at present, known about the effect of experience upon neuronal parameters. Some theories ascribe learning to changes in synaptic efficacy; this might mean strengthening or weakening of existing synapses or formation of new ones. Likewise, redistribution of synapses on the dendritic surface, a change in the neuron size or shape by growth and branching, or chemical modifications of its membrane could lead to the same result. The point to be emphasised is that, although there are several eminently reasonable and realistic ways in which information processing characteristics of nerve cells could be changed, we do not know how this is, in fact, done. This is not surprising because single neuron physiology is a field still in its infancy. Nearly all that we know about synapses has been learnt through experiments on frog muscles or motor neurons in the spinal chord of cats. No one has yet looked at the synaptic physiology of neurons that might mediate learning and memory.

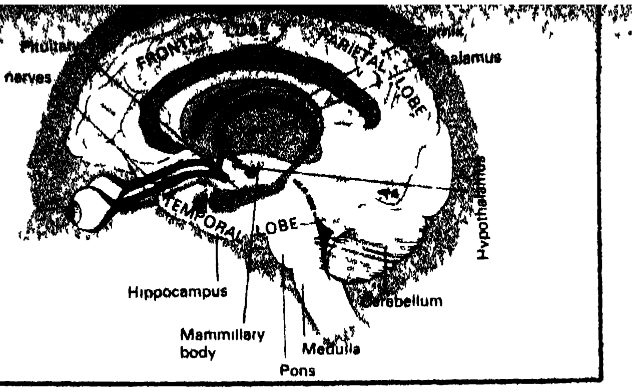


Fig. 6 Cross-sectional side-view of the brain showing deeper structures

Short-term memory

We can learn and remember in a matter of seconds Memory episodes of this order of duration play an important part in our everyday life. It is a major finding of experimental psychology that memory can be of two distinct types short-term memory and long-term memory. The difference between these two types of memory may be seen from the following experiment:

We train an animal, let us say, a rat, to perform some task. Our rat may, for instance, be trained to avoid a particular turn in a maze. Sometime after the lesson is learnt, the animal is given a massive electric shock, in its head, which has the effect of confounding all ongoing electrical activity in the brain. After the rat recovers from the somewhat unpleasant effects of the shock, its performance in the maze can be tested again. We obtain the following interesting result. If the shock is given within five minutes of the training, it completely prevents learning. At 15 minutes, there is major interference with retention, while after one hour, the shock has practically no effect. The experiment shows that, for the first few minutes, memory exists in a particularly labile form. It can be completely disrupted by the *electroconvulsive* shock. Progressively, memory is converted into a more stable form, resistant to electric shock. The conversion of short-term memory into long-term memory is called 'consolidation'. Several treatments such as trauma (a hard knock on the head), low temperature and barbiturate anaesthesia have the same effect as electroconvulsive shock in preventing consolidation of short-term memory. The agents that produce *amnesia* (loss of memory) are known to affect the electrical activity of nerve cells. It is, therefore, likely that the mechanisms underlying the initial stages of memory are electrical. The brief period required for short-term memory to form is too brief to permit any appreciable chemical synthesis or growth in the nerve cell.

Fixation amnesia is a defect of short-term memory. Patients suffering from this disease are not able to retain experienced events for more than a short period. On the other hand, they can recollect, perfectly well, incidents in their lives before the onset of amnesia. The consolidation of short-term memory, in these patients, into stable forms appears to be blocked. The predicament of fixation amnesics is illustrated by the story of an old woman afflicted with this disability. The woman was taken to her village which she had not visited for over 20 years. Next day, when asked if she remembered her village, the woman replied, " Yes, almost as if I was there yesterday ". There is evidence that fixation amnesia is caused by destruction of nerve cells in parts of the brain called mamillary body and hippocampus (Fig. 6), which suggests that these regions are involved in the " stamping in " of memory

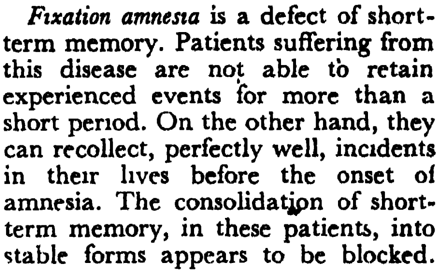


Fig 7 Memory is made up of components which are distinguished by their respective modes of forgetting. (Left) Short-term memory consists of a very rapidly forgotten part (black) and intermediate memory (coloured). (Right) Gradually, short-term memory is converted to lasting memory traces

There is yet another kind of amnesia called *retrograde amnesia.* This is a temporary loss of memory which sometimes happens to people after brain concussion. On recovery, the amnesics regain their memory in a very peculiar manner. At first the oldest memories come back, followed by the more recent ones, strictly in the order in which they were formed until at last the events a few minutes before the accident are recalled. There is always a short period just before the accident which can never be remembered. This is the period of which the memory was never fixed. I had a brain concussion once. While playing Holi, I slipped and fell on a bucket which knocked me out for a couple of days. But that is what I was told by others. I have a perfect recollection of walking with the bucket in my hand but none whatever of the fall.

More refined experiments on the time-course of memory formation show that the short-term memory itself consists of distinct components. Far more information enters our brains through our senses than we can ever remember. There is a very rapid forgetting of most of this intake in less than a couple of seconds. A great deal of experience, thus, does not survive the instant of its passing and is irretrievably lost. The very first phase of memory probably exists as a pattern of neural firing in the brain for a brief period and then dies out as it is replaced by succeeding patterns of activity. If any of this experience is to last, it must be selectively preserved and re-established as a distinctive pattern of a somewhat longer duration. We might call this second stage, intermediate memory.

Following D. O. Hebb, physiologists often invoke reverberating circuits for short-term memory. The all-or-none action potentials circulating in neuronal pathways provide one conceivable mechanism for maintaining early memory. There is no direct experimental evidence that this is so. On the contrary, some of the evidence tends to support arguments against the idea that short-term memory traces consist of nerve impulses continuously circulating in closed neuronal nets.

Some have suggested that the relevant electrical signs of short-term storage are to be found in slow potential changes arising from oscillations of synaptic potentials. Such oscillations show up as characteristic brain waves in EEG (electroencephalogram) records.

Lastly, electrical memory could be stored in special registers analogous to those used in electronic computers. However, there is no evidence to show that such registers exist.

Experimental conditioning and long-term memory

While it seems very likely that the mechanisms for storing labile short-term memory are electrical, this could hardly be the case for the stable memory which arises after consolidation. Electroconvulsive shocks, concussions or anaesthesia so deep as to cause electrical silence, leave long-term memory undisturbed. Stable memory, therefore, cannot be based on continuously circulating impulses or other electrical states of nerve cells; it requires a more enduring pattern of brain modifications It is believed that long-term memory involves morphological or chemical alterations in nerve cells. The essential idea is that recurrent impingement of neurons by impulses or " synaptic bombardment " causes a durable change, making a particular neuronal circuit more susceptible to subsequent activation. Before we come to more explicit versions of this hypothesis, let us examine some of the experimental methods used to investigate memory consolidation.

Most experiments on consolidation make use of some form of training or conditioning. The best known among such experiments are those carried out by Ivan Petrovich Pavlov at the Medical Academy in St. Petersberg (now Leningrad) in the USSR. Pavlov began the studies which won him lasting fame and a second Nobel Prize after he had already received a Nobel Prize for his work on physiology of digestion in 1904. Pavlov's experiments were concerned with salivation in dogs. When a dog eats food, saliva flows in its mouth. This is an automatic reflex reaction that does not have to be learnt. A dog might also salivate when he sees a juicy morsel of food. This reaction is not an innate reflex and will not occur in a puppy. The dog learns to salivate somewhere along the line, watching its food before eating it. In the 19th century, people who considered this matter (in so far as they considered such matters at all) were likely to say that the dog had learnt that the visual image of food meant food, and salivation was a result of expectation. Pavlov wasn't so sure. He wasn't at all sure what words like ' learnt ' and ' expectation ' meant.

Pavlov's experiments were extremely simple. A bell was rung; at the same time a door opened and a tray of delicacies appeared before the dog. Naturally, the dog salivated. The far-reaching result was that after a few trials, the bell itself was enough to start salivation whether or not there was any food in sight In Pavlovian terminology, the *conditioned stimulus* (the sound of the bell) had replaced the *unconditioned stimulus* (the food). This type of conditioning is called *classical conditioning*. Pavlov found that almost all stimuli, including usually painful ones, can be used to elicit salivation, if paired often enough with an unconditioned stimulus. The dog could be conditioned to salivate and wag its tail with pleasure in response to light, sound, touch, electric shocks or pin-pricks.

The importance of Pavlov's discoveries lies in the fact that *conditioned response learning is extremely widespread and appears to be a fundamental property of all neural organisation.* Pavlov recognised conditioning as a common ingredient of much of animal and human behaviour.

Classical conditioning is a simple form of learning. The experimenter contrives to associate an arbitrarily chosen stimulus with an innate, primitive response of the subject, usually a reflex activity such as salivation, knee-jerk, pupillary contraction and the like There is a second form of conditioning called *operant* conditioning in which an irrelevant stimulus can be used to elicit a behaviour normally under the voluntary control of the animal. R. M. Yerkes found some 50 years ago that earthworms can be taught to turn right. A worm is placed at the base of a T-shaped tunnel. If, at the cross-bar, it turn right, the worm reaches a bed o succulent mud; if it turns left, it i punished with electric shocks. Soo the worm learns to turn right consistently. The element of reward o punishment is an essential ingredien of operant conditioning. The traine makes use of the natural *repertoire* o the animal's behaviour moulding i towards desired ends by a suitabl system of reward and punishment. A carefully chosen combination of operant conditioning steps can lead t startling accomplishments. By suc methods pigeons have been taught t play table tennis, seals to blow horn and bears to ride bicycles.

You might object that the mechanical and automatic learning o worms and pigeons has little to d with our own thoughtful learning Think of the worm at the cross-bar o the T-maze. When it makes the right turn, the worm has some way to g before enjoying the pleasures of th cool mud. Some activity in its neuron must make an *impression*, lasting lon enough to be reinforced by th reward. The worm's education is no so automatic after all. Consider th matter a bit further. In a standar operant conditioning paradigm, a ra is taught to press a lever when a re light goes on This is simple to do Occasionally, the rat will step on th lever by accident If the red ligh happens to be on, we might rewar the animal by releasing a pellet o food He will very soon learn t obtain food by pressing the leve whenever the light goes on. If such behaviour is exhibited by a child o perhaps a chimpanzee, we are likel to say that he ' gets the idea ' and use ' thinking '; in the case of a rat o some lowlier animal we are apt t imagine that what is involved i mechanical and automatic. Experiments indicate that the underlyin mechanisms in either case must b similar.

Conditioning experiments show tha

Photograph taken sometime in the first decade of this century shows Pavlov (centre) demonstrating his famous experiment on conditioning neural mechanisms exist that will establish new patterns of sensory-motor responses. The connections between the triggering sensory input and the selected behavioural output are strengthened in preference to other alternative motor programmes. It is natural, therefore, to look for possible neural changes that might accompany conditioning as the basis of memory. Experimenters have been searching hard for such neural correlates of conditioning in the hope of obtaining clues to the nature of learning and memory.

Electrical concomitants of learning and memory

The electrical activity of nerve cells can itself be conditioned by appropriate pairing of stimuli. A low frequency stimulation of the central nucleus in the *thalamus* causes a brief shift in surface potential (Fig. 8). If the electric stimulus is paired repeatedly with a sound tone, after about 30 trials the thalamus cells respond to sound alone. Numerous instances of such ' neuronal conditioning ' are known The fact that sensory or motor neurons can be conditioned by Pavlovian techniques is, by itself, neither surprising nor particularly informative. After all, if overt behaviour can be conditioned, one must expect to find this reflected in neuronal firing On the other hand, a study of conditioning and memory at the level of neuronal activity raises the hope that, by this method, one might learn something about the primary mechanism

Of more direct relevance to the establishment of memory are certain experiments which claim to modify learning by electrophysiological intervention Rabbits were trained to lift their paws in response to flashes of light. It was found that injection of negative charge in certain areas of the visual cortex blocked the retention of experience acquired during electrical stimulation. Injection of positive charge (anodal stimulation) in the same areas had no effect.

Other electrophysiological experiments have been concerned with identifying specific electrical concomitants of learning and memory by analysing the non-specific electrical signals called slow waves emanating from different parts of the brain. It is believed that the slow waves recorded from a region are composite representations of excitatory and inhibitory post-synaptic potentials and other long-lasting potential changes in the neurons of that region. Experimenters have examined changes in the level of synchrony or intrinsic brain rhythms during conditioning. Similarly, characteristic changes in evoked potentials correlated with the establishment of conditioned responses have been observed There is voluminous literature on this area and the subject tends to be somewhat technical I will, therefore, restrict myself to just one example.

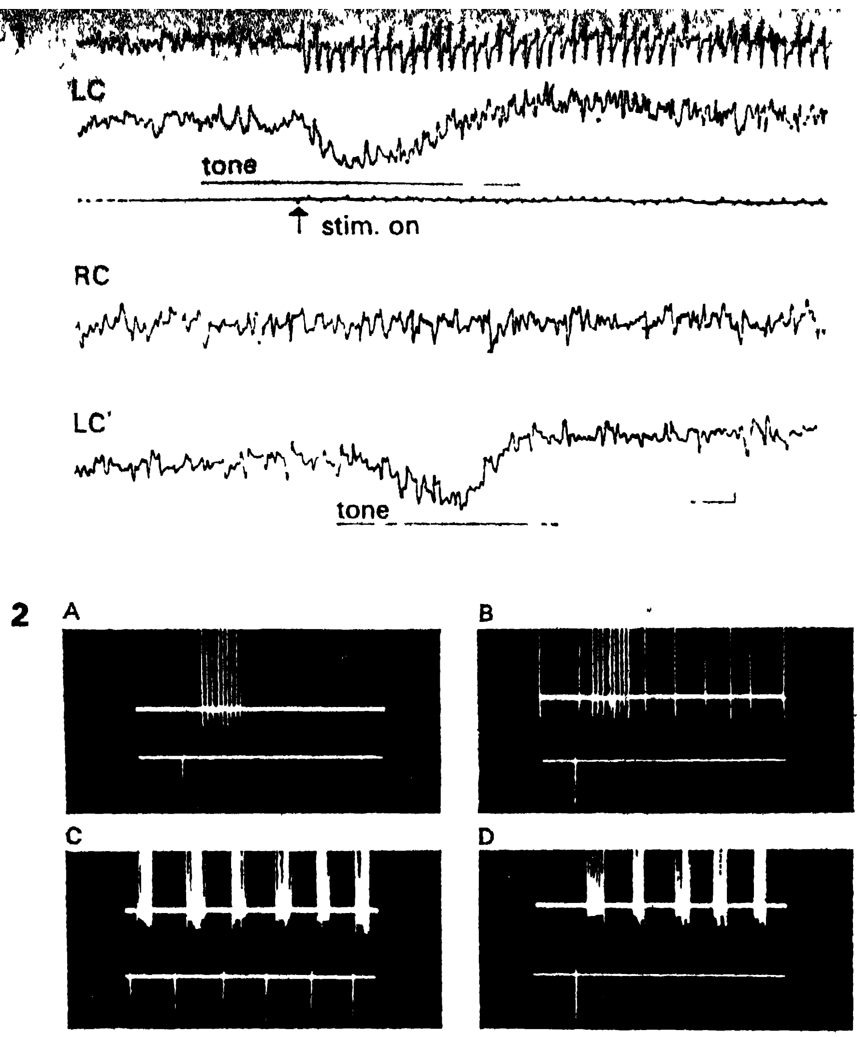


Fig 8 Electrical conditioning of nerve cells (1) Electrical stimulation of thalamus causes a slow potential change. When electrical stimulation is paired with sound tone repeatedly, the tone can by itself elicit the response (2) Single light flash causes nerve cells to fire, repetitive flashes cause repetitive bursts. After several repetitive stimuli, a single flash may evoke a repetitive response

W. R. Adey at the University of California at Los Angeles found a special six cycles per second wave in the brain of a cat during maze learning. This wave spreads to various regions such as reticular formation, brainstem and visual cortex believed to be involved in the learning task. Every time the cat made a mistaken move in the maze, the phase relationships of the six-cycle wave in different regions underwent characteristic changes. Adey concluded that the *approach wave* must be an *electrical signature* of some brain mechanism which is the basis of learning and memory.

Studies on electrical correlates of learning have produced some interesting and intriguing observations, but so far, on the whole, do not throw much light on the mechanism of memory consolidation.

Formation of nerve connections

Let us now examine the possibility of new morphological connections between neurons as a mechanism of long-term memory. Although the overall organisation of the nervous system is quite securely specified by genes, the rigidity of these specifications varies within wide limits between different species. The stereotyped behavioural repertoire of certain insects appears to be wired into a fairly invariant pattern of nerve connections. As we move higher up in the scale, the situation changes. In mammals, too, a large part of the network must be strictly prewired; this would include parts of the old brain controlling vital functions or innate unlearnt responses. Areas such as the sensory-motor cortex or the cells of the visual cortex seem to be fairly closely determined, although the experimental evidence here admits of some plasticity, regions of the cortex serving complex and elaborate functions may, on the other hand, possess much greater variability of connections.

Our views about the nature of associative connections have, in the past, tended to oscillate between two extremes Some have looked upon the entire network as an initially undifferentiated " equipotential " system in which dynamic structures arise " by uniting distant points in a common task ". These structures are believed to be " complex, plastic and self-regulating ". The opposite view emphasises the prewired, " deterministic " character of the neural ensemble. Long-term memories are believed to depend upon changes in pre-existing synapses.

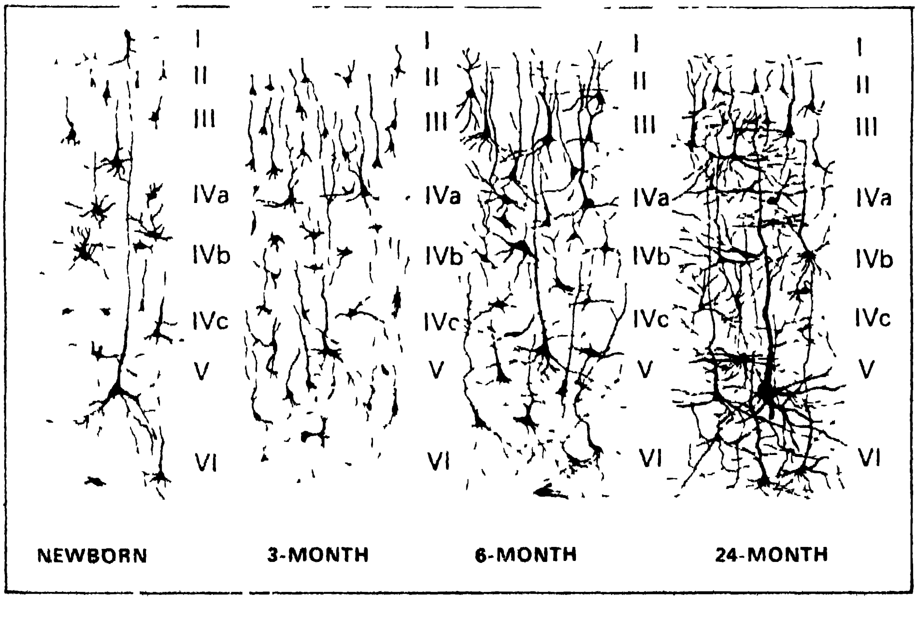
Brain cells do not divide, but they can grow new branches. In the first few years of life, the cortical cells in the brain of a child branch extensively (Fig. 9). Along with this profusion of neural connections goes the acquisition of new abilities, including learning ability. It is a reasonable guess that the two processes are connected.

If continued branching and interconnection of neurons is to serve the needs of memory, it must somehow be coupled to experience. Hubel and Wiesel were the first to study the effect of sensory deprivation on the nerve cells in the cortex of newly-born kittens. They found that the circuits that analyse visual input to the cortex are present at birth. Sensory deprivation for particular types of stimuli causes degeneration of neurons, leading to a selective loss of feature detectors. Others claim that the final wiring of ' analyser circuits ' may itself be aided by visual experience. Be that as it may, these experiments point towards possible mechanisms that give rise to experience-dependent connectivity.

The brain contains large numbers of cells called glia. The glia form a matrix in which the neurons are embedded. It has been proposed that the glial cells can somehow guide the growing neural branches to form the right connections Glia divide while neurons do not. The electrical activity in the neurons could conceivably stimulate the surrounding glia to multiply and, in turn, reinforce certain connections. All this is pure conjecture. As Sir Bernard Katz has said, the only thing common between glia and memory seems to be that we know little about either.

In short then, our knowledge of mechanisms that might regulate changes in neuronal connections is extremely inadequate. In particular, we know next to nothing about how experience might modulate these connections. Long-term retaining by the nervous system requires persistent changes in the brain. But, as yet, these changes are not accessible to methods of physiology and anatomy, and not much can be said with confidence about their nature.

Fig 9 The neurons in the cortex of a child continue to branch and form new connections in early years



Localisation of memory

If we do not know what memory traces are, can we say something about *where* they are? Nerve cells in precisely marked parts of the cerebral cortex control sensory and motor functions of the animal. As shown by the remarkable experiments of David Hubel and Torsten Wiesel on the visual cortex, the cortical cells that analyse characteristic features of the sensory input such as shape, colour and movement are stacked in an orderly system of columns and rows. Are the cells dealing with functions such as learning and memory also localised? The above question has occupied the attention of neurologists for a long time, being connected with the larger question of localisation of higher mental functions.

Franz Gall (1825) was a leading anatomist of his time who held that each mental faculty was located in a definite part of the brain. Gall constructed detailed phrenological maps in which domestic instincts, destructive inclinations, attraction to food, aptitude for education, love of parents, self-esteem and other such traits were localised.

The opposite view was that there are no essential organs for mental functions and there is no necessity for them. In the words of Joseph Loeb (1900), " The assumption of centres of association is just as erroneous as the assumption of a centre of co-ordination in the heart. Association is, like co-ordination, a dynamical property determined by the conductivity of the protoplasm. Associative processes occur everywhere in the hemispheres "

With increasing interest in associative conditioning at the turn of the 20th century, it was natural for psychologists to examine the effects of cutting nerve connections on learnt responses. S. I. Franz (1907) was perhaps among the first who combined psychological testing with neurosurgical lesions. Experimenting with cats and monkeys he found that, with the destruction of frontal lobes, " recently formed habits were lost although long-standing habits were not affected " Lesions in other parts of the cortex did not have this effect. Franz concluded that frontal lobes are employed in the formation of simple associations

The Harvard psychologist K. S. Lashley and his students carried out a series of brain ablation experiments on rats to determine the role of cortical connections in memory storage. They found that extensive cuts in the cortex do not impair performance in mazes. When large pieces of cortex were removed, it appeared that the retardation in the learning of complex mazes was proportional to the mass of cortical tissue destroyed but relatively unrelated to where the cut was made. This is Lashley's so-called ' Law of mass action '. Lashley also found that for the type of tests used by him, a given cortical area could serve two different functions and, conversely, the same function could be carried out by different parts of the

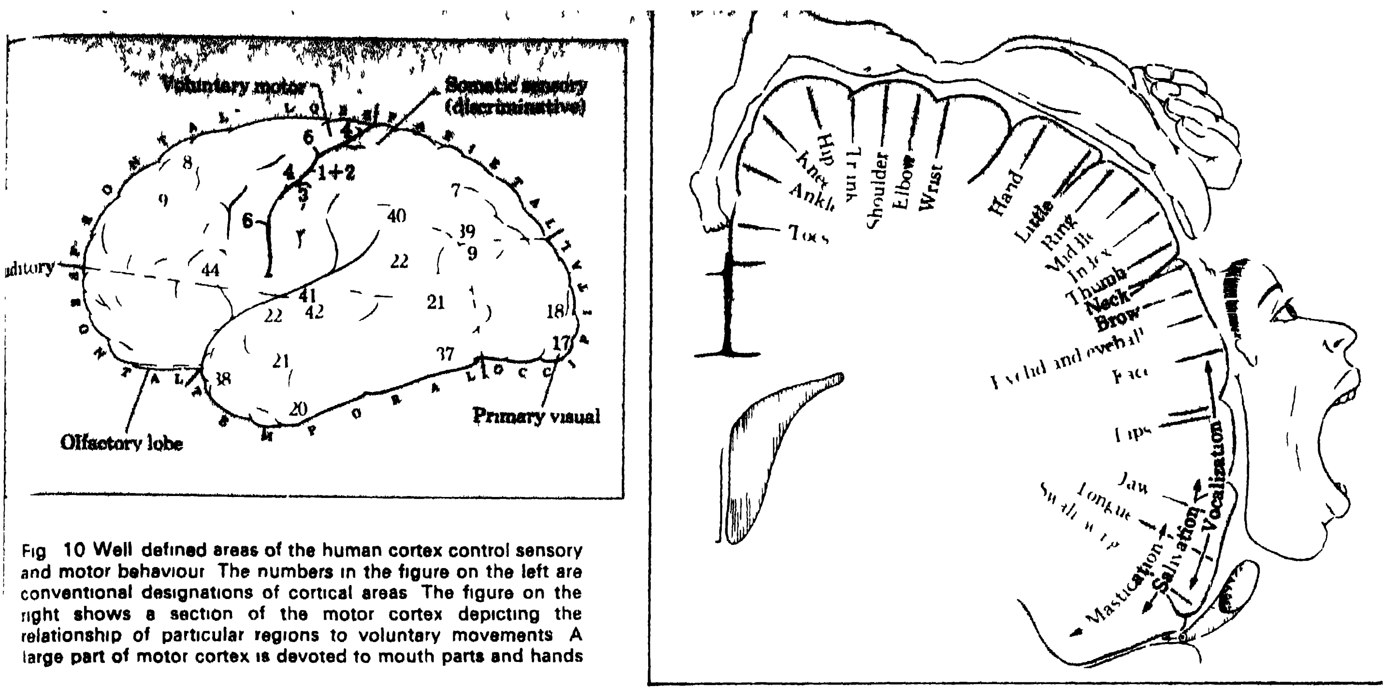


Fig 10 Well defined areas of the human cortex control sensory and motor behaviour The numbers in the figure on the left are conventional designations of cortical areas The figure on the right shows a section of the motor cortex depicting the relationship of particular regions to voluntary movements A large part of motor cortex is devoted to mouth parts and hands

cortex ("Law of equipotentiality") Experiments rather similar to those of Lashley on localisation of discriminative memory have been carried out with octopuses (by Boycott and others) Here, too memory somewhat like the Almighty seems to be everywhere but nowhere in particular

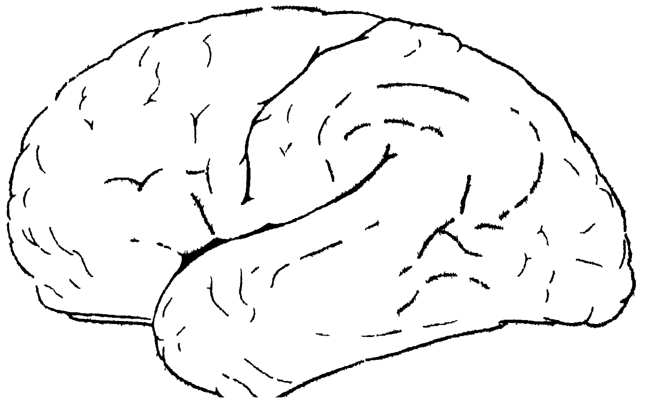
The principles of "equipotentiality" and "mass action" as demonstrated in maze learning by rats, may or may not be applicable to human memory As long ago as 1876 Ferrier had removed the entire frontal lobes of monkeys and shown that the animals retained appetites instincts, sensory abilities and motor faculties Yet he noted a subtle change of behaviour ascribable to loss of attentiveness and intelligence C F Jacobsen found that lesions covering both sides of the frontal association areas of monkeys completely blocked the ability to carry out delayed response tests, where the animal has to recall an environmental cue from memory After the operation the monkey is unable to remember under which of two cups food is concealed At the same time his performance in other problem boxes or visual discrimination tests is not affected The interpretation of ablation experiments is beset with numerous difficulties and one has to beware of accepting simple interpretations

I will now briefly discuss some work on the cortical localisation of speech which appears to me significant in relation to the problem of memory storage The French neurosurgeon Paul Broca examined the brains of many patients who had developed speech defects He found that these patients very often suffered from damage to brain cells in an area located along the side of the dominant left hemisphere Broca concluded that this was the speech area [See Fig 1 in Prof Narasimhan's article, p 28)] It became the prevalent practice to carefully avoid incisions in Broca's speech area during tumour surgery Wilder Penfield, working at the Montreal Neurological Institute, suspected that not all of the large left cortical area assigned by Broca to speech was really so He therefore decided to carefully map the speech area by electrical stimulation techniques

The method used by Penfield was an extension of the technique that had been successfully employed to map the sensory and motor areas of the cortex A stimulating electrode was placed in the cortex and the patient was engaged in a conversation while being electrically stimulated When the electrode entered the speech cortex, the stimulus strongly interfered with speech in a remarkably characteristic way On being asked to name an object in a picture, the subject would say, 'Oh! I know what it is, that's what you put in your shoes' If the stimulating current was switched off, he said, "Foot" There was no interference with the control of speech organs The patient knew what he wanted to say, yet he could not somehow get the right words This experience is extremely baffling for the patients They feel frustrated at not being able to find the words they are certain they know and they try to get the nearest synonymns After the stimulation was stopped a patient remarked, "I couldn't get that word 'butterfly' and then I tried for 'moth'" This effect is quite different from the effects of interference in areas of motor cortex controlling speech organs Stimulation of speech motor areas causes slurring or distortion of words or sometimes simple vocalisation, that is to say, emission of long-sustained vowel sounds

Using electrical stimulation methods Penfield and his associates were

Fig 11 Speech areas mapped by Penfield



able to map out three clear areas in the cortex (Fig 11) The three speech areas, as a rule, are located in the left hemisphere Contrary to expectation, this is also true of patients who are left-handed There are no significant differences in the speech disturbance produced by stimulation in these areas

Clearly marked speech areas in the cortex are of obvious significance from the point of view of localisation of memory circuits Language is an entirely acquired function Learning a new word is a special experience for each person The existence of distinctive regions in the cortex that are devoted to speech might, therefore, throw light on neural organisation of long-term storage

Penfield found that occasionally some of his patients had their speech areas in the right hemisphere These invariably turned out to be people who had suffered brain damage in the left hemisphere early in life The organisation of the speech cortex thus exhibits a certain degree of plasticity, but this plasticity does not extend to adulthood Those who suffer head injuries later in life are not able to transfer their speech functions to the right hemisphere Some patients who had received extensive injuries in speech areas in the past had transferred their speech functions to neighbouring healthy regions of the cortex

In addition to plasticity, the speech areas of the cortex also display obvious redundancy Excision of one of the three results in transfer of speech functions to the other two Penfield found that he could completely remove the upper of the three speech areas without causing more than a temporary disturbance in speech He could also make incisions completely encircling these areas without any serious effects, showing that the connecting links between the three areas did not go through the cortex This conclusion is supported by direct anatomical observations Each of the three speech areas sends tracts of nerve fibres downwards to the thalamus in the brainstem (Patients who develop *thalamic* tumours also sometimes suffer from characteristic speech defects) These fascinating studies are described in a very readable book *Speech and Brain Mechanisms*, by Penfield and Roberts

While exploring the human cortex with stimulating electrodes, Penfield made another startling discovery Electrical stimulation would sometimes induce a patient to recall past events with great vividness These ordinary incidents which the subjects had experienced and had no particular reasons to remember were suddenly forced by the electrical stimulus on their consciousness The first patient recalled an early childhood episode with a naturalness as if she was reliving the incident A young man saw himself with his cousins in South Africa, he felt he could hear them talking and laughing One woman heard the voice of her son in the backyard another the singing of the Christmas choir in a church in Holland These elicited experiences appear very real to the patients and are described in great detail The vividness of these recollections clearly differentiates them from ordinary memory, yet the subjects at the same time know that they are in the operation room When questioned afterwards, they describe experiencing two different awarenesses at the same time Penfield calls this “ double consciousness ” Sometimes the electrical stimulus starts a narrative which interrupted by shutting off the electrode If the stimulus is renewed, the same experience starts again at the beginning

Penfield's experiments on electrically-triggered recall have been repeated in other laboratories The cortical ‘ recall areas ” are confined to the two temporal lobes on the lower left and right sides of the brain The fact that the temporal lobes are the only areas in the cortex where electrical stimulation causes recall of experience need not of course mean that this is where the actual memory is located It is possible that the induced signals are conducted to some other part (or parts) of the brain where memory traces (whatever they are) are stored It could be that the memory traces are not in the cortex at all, only the cortical access areas are localised Just what these remarkable observations mean we do not yet understand, we are nevertheless left with an inescapable impression of orderliness in the neural organisation of memory

Roger Sperry and his associates at the California Institute of Technology have carried out a series of very remarkable experiments on the so-called split-brain animals which throw

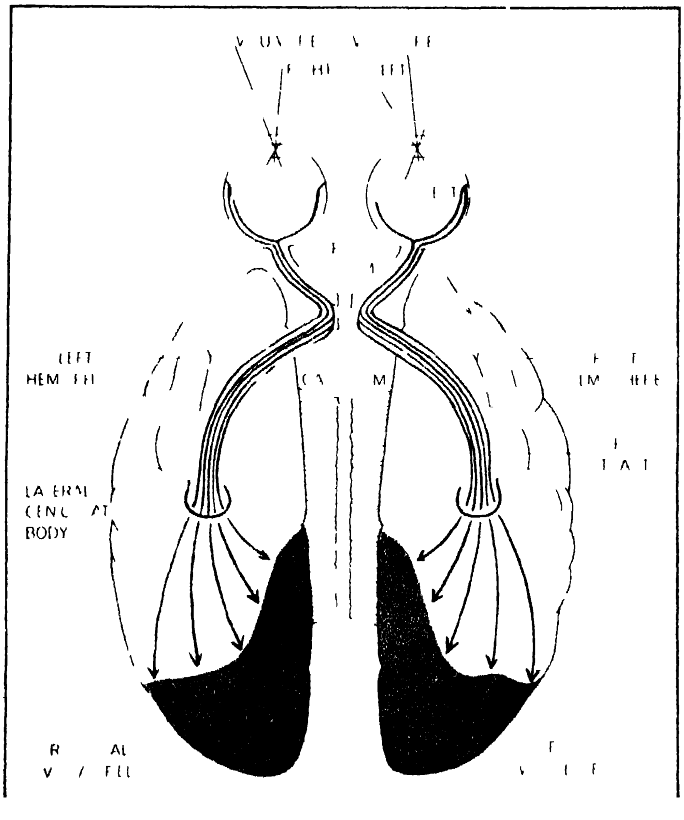
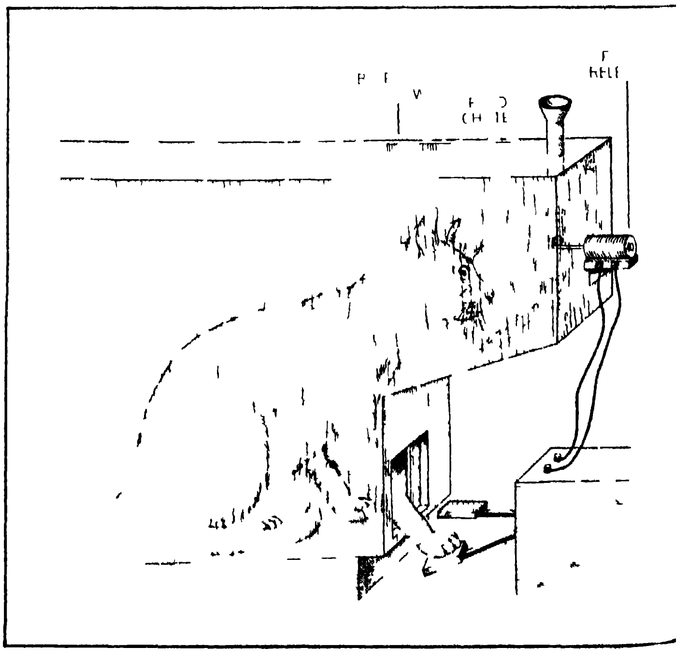


Fig 12 The two halves of the cortex can be disconnected (split brain) by cuts in the optic chiasma and the *corpus callosum* (left) The cat (below) is trained to obtain food by pressing an appropriate pedal with one or the other of its feet A split brain cat cannot transfer its learning from one foot to the other



interesting light on the issue of cortical localisation of discrimination memory. Cats can be trained to open a door in response to a visual cue. The chosen pattern, a circle or a square, is displayed on the door and, on opening it, the cat either receives a reward (food) or punishment (admonition) depending upon the correctness of the choice. Within about 40 such trials, a normal cat learns to make correct choices nearly all the time.

The nerve fibres going from the two eyes to the brain are shown in Fig. 12. At a point in the optic tract called the optic chiasma some of the fibres cross over to go to the other side of the brain. Each eye is thus connected to both the right and the left hemisphere. The nerve fibres at the cross-over point can be cut in the manner shown in the figure. In such chiasma-sectioned animals, the information from the right eye is available to the right side and from the left eye to the left side alone. Sperry taught chiasma-sectioned cats the visual discrimination task with one eye, the other being closed with a patch. The patch was then shifted to the trained eye and the cat's discrimination tested with the untrained eye open. The cats performed quite correctly showing that the lessons learnt through one eye were available to the other. The two halves of the cortex are connected together by a thick tract of fibres called the *corpus callosum*. If the discrimination learning was indeed stored in the cortex, the *corpus callosum* could be the pathway along which it was transferred from one side to the other. Sperry, therefore, cut the *corpus callosum* before training the cat. He found that such cats, trained with one eye closed, could not perform the prescribed task through the other eye. *Callosum-sectioned* cats could be trained to open circled doors through one of their eyes and squared doors through the other. Their performance in the discrimination test always corresponded to the training received by the eye which was used. C. B. Trevarthen, one of Sperry's colleagues, has devised a special pair of spectacles for cats so that, in polarised light, they see a circle with one eye and a square with the other at the same time. Such cats can be taught opposite discriminations simultaneously. The cat does not merely have two disconnected halves of the cortex, there are indeed two cats in one.

The significance of Sperry's experiments for memory storage is this : the memory traces for the visual discrimination task must be in the cortex and not, for instance, in the brainstem, as severing the *corpus callosum* makes the discrimination memory non-transferable to the opposite side. With the *corpus callosum* intact, the memory traces are laid down in two copies, one on each side, so that if the two halves of the cortex are severed after training, the cats trained through one eye can discriminate correctly with either of the eyes open. Jan Bures of the Czechoslovak Academy of Sciences has shown that if conduction of nerve signals along the *corpus callosum* is blocked during training, transfer of memory from one side to the other does not occur after the block is removed and only one copy of the memory remains. Sperry and his associates have extended the split-brain experiments to other animals including monkeys and humans and employing other sensory modalities such as touch or hearing. In certain experiments they were able to remove large parts of the cortex and thus ' corner ' the memory traces for tactile discrimination to the sensory-motor area. In comparable experiments with rats, Bures has obtained evidence for localisation of visual discrimination memory in the region of visual cortex. In either case, some of the discriminative memory traces seem to be laid close to the area of the primary sensory modality that was employed in learning the task.

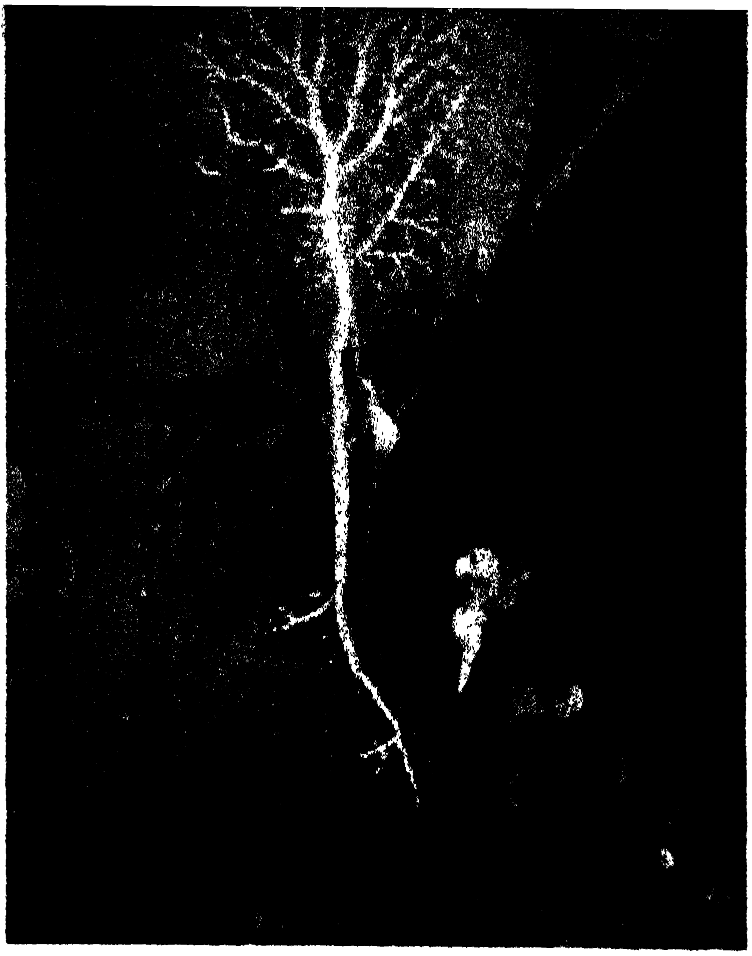


Fig. 13 Neuronal pathways can be located by injection of fluorescent dyes. The coloured photograph shows the branching out of the dendrites in a section of an insect brain. Such techniques are now beginning to be used in the study of the neuronal network of mammals

From the experiments described above, it would seem that the brainstem did not actively contribute to memory, but this is not always the case. When learning involved the simultaneous use of two different sensory modalities such as visual and tactile, the memories stored in the two halves of the cortex, which are not transferable from one to the other, could be integrated. This obviously requires the participation of the brainstem. There are many other implications of the studies on split brains which go beyond the scope of this article. There is a fascinating account of the experiments on human split-brain patients by Gazzaniga in the book *Bisected Brain*.

From the point of view of localisation of memory, the answers that emerge are clearly not simple. The plasticity and redundancy of connections in the brain made it difficult to obtain evidence of localisation in ablation experiments of the type done by Lashley. Connections are formed during learning that join more than one part of the brain into a learning system which includes not only the cortex but also other parts of the brain. The system is not easily disrupted because of its distribution and parallel connections. Memory may nevertheless be localised in that the firing of particular groups of cells in this system might correspond to activation of a specific memory.

A somewhat different way of looking at memory is to conceive of it as a coherent pattern of activity in a volume of cells in which the set of cells contributing to the pattern might change. In this system, different items of information need not be coded by different cells. The emphasis, in the second view, is on the activity pattern and on the fact that a cell may participate in more than one such pattern

The two ways of thinking about memory connections are not mutually exclusive and the actual situation probably represents a combination of the two Clearly, the naive pictures of functional localisation reminiscent of early phrenology cannot be entertained. At the same time the evidence points towards an orderly organisation of discriminative memory.

Sushma

Drawing based on Rodin's famous sculpture 'The Thinker" with the head borrowed from Vesalius's sketch (in Fig. 1, p. 16)

Biochemistry of memory

In recent years there has been a great spurt of research activity aimed at discovering the molecular mechanisms responsible for the formation of memory traces. The *raison d'etre* of this field seems to be the observation that the electrical activity of neurons is accompanied by a large increase in RNA (ribonucleic acid) and protein. Just as the structure of proteins is coded into the base sequence of DNA or its transcript, the RNA, some have argued that memory may be coded into a special type of RNA. The base sequence of this RNA is determined by the electrical activity of nerve cells. To quote Hyden, one of the early proponents of the RNA theory·

"The modulated frequency generated in a neuron by specific stimulation is supposed to affect RNA molecules and to induce a new sequence of nucleotide residues along the backbone of the molecule. The new distribution of components will then remain; the RNA has been specified. This leads also to a specification of the protein being formed through the mediation of RNA.

"By a combination of this protein with the complementary molecule, the transmitter substance at the point of contact with the next neuron, at the synapses, is activated. This allows the coded information to pass on to this next neuron."

It is not obvious how these various things happen. One can only say that, if this theory is true, it calls for the creation of a radically new molecular biology in addition to a new neurophysiology. All that Hyden observed was that, as a result of electrical activity in neurons, either in a learning situation or in situations somewhat analogous to it, the chemical composition of the cell's RNA changes.

Others have argued that RNA sequence *per se* need not be governed by electrical activity but the electrical signals could ' switch on ' the activity of certain genes to synthesise a special type of RNA. This RNA might work as an inducer of nerve connections and might be passed from cell to cell.

Yet others have maintained that it is not RNA but protein that is the thing. They have concentrated their energies on detection of new proteins correlated with the activity of nerve cells, specially during learning. Such proteins have been identified in the brains of fish and mice and at least one of them has been the subject of detailed structural analysis.

The brain cells are metabolically among the most active cells in the body and there is no significant compound in these cells that does not display a remarkably high rate of turn-over. That increased electrical activity of nerve cells is accompanied with synthesis of RNA and protein is not surprising and does not tell us much about the part these molecules play in learning and memory. If two things happen at the same time, this is never, by itself, sufficient reason to believe that one is the cause of the other.

More direct evidence in favour of the RNA-protein theory of memory has been presented in claims that compounds such as puromycin or cyclohexamide that inhibit synthesis of RNA and protein block consolidation of memory. A goldfish trained to perform a simple task when injected with cyclohexamide in its skull is said to forget what it had been taught. Conversely, facilitation of RNA synthesis is believed to reduce the time needed for consolidation. It has been claimed that RNA helps in the storage and retrieval of information The faith in RNA indeed seems so strong that some have actually administered massive doses of yeast RNA to rats and found that the injected RNA markedly improved the memory of aged individuals.

The most dramatic claims in favour of RNA-protein theories of memory come from experiments involving transfer of memory along with brain extracts from one animal to another. The stage for this branch of memory research was set by McConnel and his colleagues with their work on planarian flatworms. Planaria were conditioned to respond to light flashes. The conditioned worms were chopped and fed to naive worms. The cannibalistic worms, it was observed, learnt the light response more rapidly than their naive brothers. Treatment of the worm-chop with an RNA-degrading enzyme prevented the transfer of learning ability. McConnel's experiments were publicised several years ago by the popular writer Arthur Koestler and received a great deal of attention.

In the same vein, ability to learn a variety of conditioned responses is believed to have been transferred along with extracts made from the brains of trained rats and mice or with RNA or protein in these extracts injected into untrained recipients.

Not much need be said about these experiments. There are about as many who have failed to confirm the experiments and to obtain any evidence in favour of transfer of memory by injecting brain extracts, as there are those who have succeeded. The entire

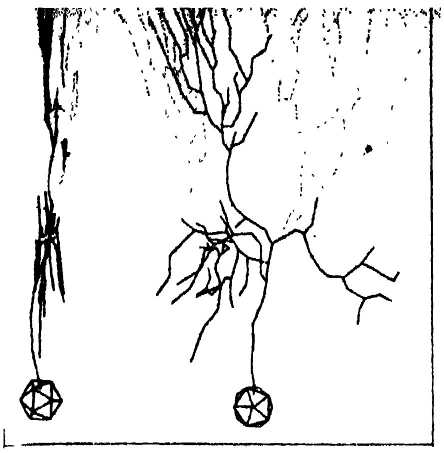


Fig. 14 Computer-aided electron microscopy can be employed to reconstruct three-dimensional views of neuronal branching. In the picture above, the computer displays two views of a reconstructed nerve cell (the figure on the left shows the figure on the right after it has been turned by 90°)

field of chemical memory transfer is controversial and not particularly illuminating.

Future prospects

If I have left you with the overwhelming impression that nothing is known about biological mechanisms of memory, I should like to end this article with some degree of optimism. It is true that, at present, not much can be said with certainty, but there are a few interesting things that we do know. From the experiments of psychologists we know the chief characteristics of memory that have to be explained and we have learnt a good deal about how nerve cells work. We can, therefore, have a better appreciation of the problem itself. Methodologically speaking, we are also in a better position to attack the problem. This is why, I believe, the study of memory mechanisms is going to be more exciting in the future than in the past.

It is not very easy to devise good experiments to study the physical characteristics of memory traces. The cross-sectional area of an average neuron is one hundred-millionth of a square centimetre. It is hard to make microscopic observations on synaptic changes or to analyse detailed electrochemical properties of a neuron before and after learning. In fact, it is quite difficult to locate *a neuron* among billions of other neurons in the brain of animals.

But difficult, in science, is never to be construed as impossible. A number of recent advances in methods of neurobiological research makes it likely that the undoable will be done. We now have experimental methods by which, with the help of minute electrodes, electrochemical changes in single neurons can be monitored. Micropipettes can be used to inject fluorescent or electron-opaque dyes in nerve cells enabling us to visualise the ramifications of dendrites (Fig. 13). Electron microscopy aided by computerised analysis can help us reconstruct neuronal trees in three dimensions with the fullest details of their synaptic organisation (Fig. 14). Powerful methods are available to trace out the connections that neurons in one part of the brain make with other parts and to study the development of these connections.

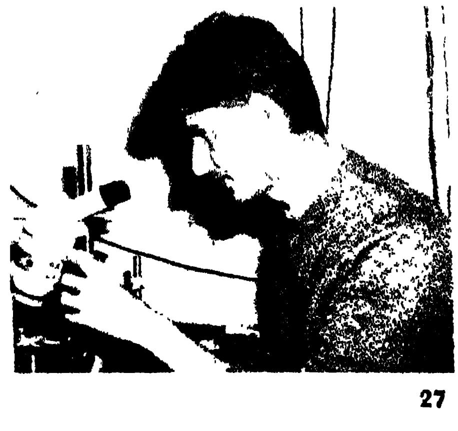
We are becoming increasingly aware of the fact that the problems of brain function have to be approached from many sides. A many-sided attack on the memory problem, combining methods of biology and psychology, can be best made in experimental animals that lend themselves well to the requirements of either approach. A great deal of exploratory work in search of such model systems for studying brain functions is currently going on. Biologists have a deep conviction in the unity of life and most of us would be willing to bet heavily on the proposition that what we might learn from crabs, flies and cats will apply to other animals including man.

The problem of memory is not one of finding a single key answer to a single question, either on the matter of its location or of its special biochemistry. The real problem is to understand how neural circuits acquire the ability to restructure themselves in response to everchanging environmental inputs. The explanations we give must account for well-established properties of memory uncovered by experimental psychology. As perceived by Quintillion nearly 2,000 years ago, memories are formed by association with previously formed memories. Secondly, memories arise in stages, first as highly transient sensory perceptions some of which are salvaged by attention-focusing mechanisms and converted into long-lasting traces. These traces can be strengthened by repetition and weakened by neglect and distraction. These and other similar psychological attributes of memory must be accounted for. At the same time our explanations must be firmly grounded in established principles of molecular and cellular physiology. The problem of memory is closely connected with that of the formation and maintenance of functional neural networks, itself a part of the larger problem of how complex biological structures develop. Molecular biology, or at least the molecular biology of viruses and bacteria, has been principally concerned with how large and complex non-repetitive molecules are constructed. The mechanisms involved are self-contained and fairly deterministically governed by the genetic programme; environmental influences enter only in a peripheral manner, as for instance, in regulating the rates of synthesis.

The developmental programmes of higher animals and plants exhibit an additional and quite novel feature which might be called *acquired variability*. These organisms modify themselves adaptively, often in very remarkable ways, in response to varying biographical experience. Jean Baptiste Lamarck mistakenly made this 'adaptive principle' the basis of his theory of evolution. Notwithstanding this misapplication, adaptive assimilation of environment must confer upon the organism great advantage to have been cultivated so assiduously by natural selection.

The mechanisms that underlie adaptive responses of multicellular organisms are just beginning to be explored. A nervous system that permits systematic modification of neural circuits in response to experiential inputs, with its concomitant memory, exemplifies the Lamarckian principle in its most sophisticated form. Memory, from this point of view, has nothing to do either with the intractable activities of a conscious soul or the passive storing of a magic molecule; it is a high biological achievement.

Professor of Molecular Biology at the Tata Institute of Fundamental Research at Bombay and Head of its Molecular Biology Group, Prof. O. Siddiqi (45) took his MSc from Aligarh University and PhD from the University of Glasgow. He worked at the Cold Spring Harbor Laboratory, NY, the University of Pennsylvania and the Laboratory of Molecular Biology at Cambridge before joining TIFR in 1962. Prof. Siddiqi's contributions are in the area of molecular genetics and genetic neurobiology. He was Visiting Professor of Biophysics at MIT and Gosney Fellow in Behavioral Genetics at the California Institute of Technology. Fellow of the Indian National Science Academy and also the Indian Academy of Science, he was awarded the Bhatnagar Prize for Biological Sciences in 1976



and Language Behaviour

R NARASIMHAN

"What is the height of Mount Everest?

I don t remember the exact height But I think it is about twenty-eight thousand feet

All of us are involved in conversations of this type throughout our adult life But I doubt whether most of us ever pause to wonder about the nature and complexity of the neural machinery that enables us to engage in such conversational interactions In order to delimit the problem somewhat more narrowly suppose we want to build an automaton say, an 'intelligent' computer – that can engage in conversations of this kind How would we go about designing such an automaton? What kinds of capabilities do we have to build into it? Clearly it must go through at least the following minimal operations (1) The incoming acoustic signals must be analysed into speech units and the sequence of speech units interpreted as meaningful English language fragments (2) Realising that the input is a question, it must be understood as relating to some identifiable part of the (internally available) knowledge of the world, (3) Based on the interpretation of the nature of the query and the internally available information, an appropriate answer must be determined, (4) Finally, a speech response must be generated incorporating the answer that has been determined Thus, we need a speech analyser and a speech generator at the input and output ends, and, in between a suitably encoded world-knowledge store coupled in some way to the analyser on the one side and the generator on the other

Compare the above design outline with this account of what a neurophysiologist thinks goes on during the course of such a conversational interaction

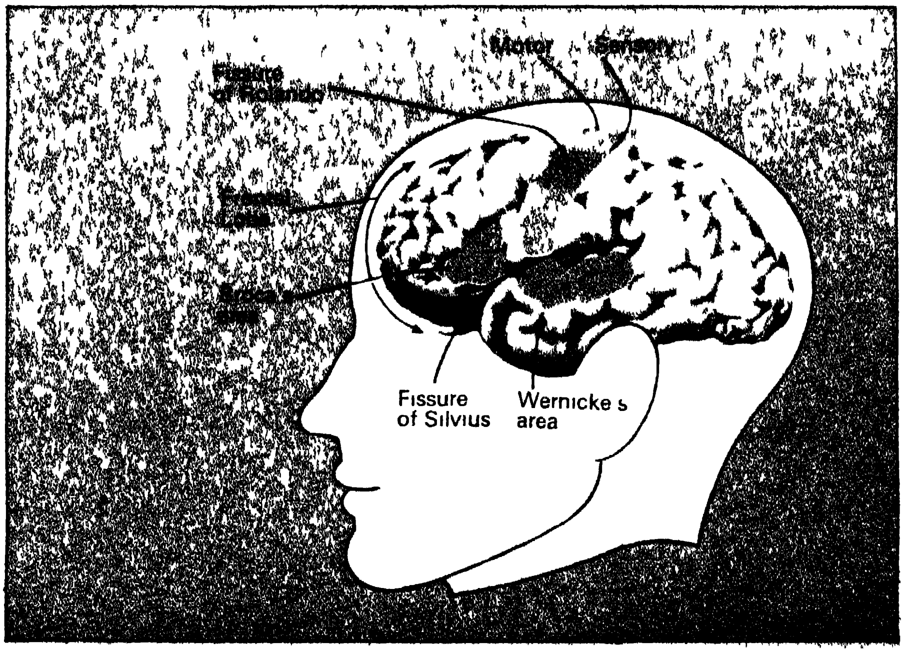
Listening to speech or reading a book would send a stream of afferent impulses flowing inward over the auditory or the visual route, through the transmission stations of the cortex, into the centrencephalic system From there the stream must somehow exert its patterned effect upon the speech mechanism of the dominant sphere Ganglionic counterparts of the words are thus activated in the speech mechanism As each word complex is thus activated, it wakens, by its own automatic reflex, the corresponding concept The connection between *speech mechanism* and *concept mechanism* is evidently reflex and automatic The act of speaking probably depends upon the functional action of the centrencephalic system It accepts the word patterns from the speech mechanism and sends out a stream of voluntary impulses through the cortical motor stations of voice control or hand control

The above quotation is taken from Penfield's description in the book by Penfield and Roberts The functional units that he postulates — the auditory analysers, the speech mechanisms and the concept mechanism (or concept 'storehouse") — are seen to be quite analogous to the engineering counterparts we had earlier sketched for our hypothesised automaton Intuitively, not only do these design details sound plausible, but it is difficult for us - according to our current ways of analysing the problem — to see how else such behaviour could be accounted for (or synthesised using a computer) Nevertheless, an explanation along these lines raises more problems than it seems to solve Some of the new issues raised would seem to suggest that there must be basic flaws in the way we tend to approach the problem

Consider, for instance, the memory mechanisms that must underlie the neural processes giving rise to language behaviour as hypothesised above For every language item this explanation calls for three internal representations one as the output of the speech analyser, the second as the input to the speech generator, and the third as part of the concept mechanism We have no clue as to the nature of these internal representations and their functional couplings The notion of a 'concept mechanism or a concept store' is, to begin with a highly non-informative one What is our concept of a 'chair or of 'Mount Everest ' How are they represented inside us? Are all concepts analysable along comparable dimensions? Some concepts, like 'chair' for example, are picturable But what about concepts like freedom' or 'grammar '?

The idea that language interactions are analysed and understood in terms of words (what one might call the dictionary-view of language behaviour) is known to be quite untenable Again there is the problem of *serial order* that has to be accounted for as Lashley pointed out in a seminal paper over two decades ago Human (and also other animal) behaviour is highly integrated along

Fig 1 The left side of the human brain showing the speech areas as mapped by Broca and Wernicke



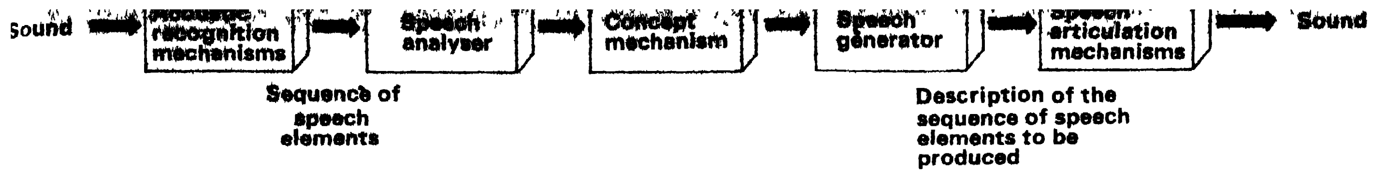


Fig. 2 An engineering model of speech analysis, understanding and generation system. The important functional units are designated within the boxes. Language disorders of various kinds that have been observed can be related to the malfunctioning at the interfaces labelled 1, 2, 3 and 4 in this model (see text for details). Computer simulation studies of language understanding and usage are based on models of this kind. Current neurophysiological ideas also use similar models. Nevertheless it is argued in the text that models such as these must be wrong in essential details

the time dimension. This is especially true of language behaviour. Speech cannot be understood by interpreting words one at a time in the order in which they are received. For instance, language is full of homonyms whose meanings cannot be determined without the use of contextual clues. Consider the sound corresponding to 'right' as it occurs in this example from Lashley's paper: "The millwright on my right thinks it right that some conventional rite should symbolise the right of everyman to write as he pleases" In speech the contextual clues may be scattered over a wide temporal interval Computer simulation studies based on models of the kind we discussed earlier show that the processing aspects needed to cope with context, presupposition, etc could become extremely complex. But in real life these problems do not seem to pose excessive difficulties. This would seem to indicate that our models do not mirror in essential details what goes on in our neural systems in using and understanding language.

To avoid any possible confusion I should perhaps emphasise that throughout this article I restrict my considerations to the naive, conversational language behaviour of normal human beings. As you may have guessed from the discussions so far, the neural mechanisms that support language behaviour are not restricted to memory. In fact, when one deals with complex behaviour, such as that involved in using and understanding language, it is very difficult to isolate the role played by memory and study it as if memory were a well-identifiable, distinct unit. As we shall discuss in detail later in this article, we should not think of memory as a passive store. Processes associated with memory (recalling, remembering, recognising) are active, creative processes. Such processes enter into language behaviour in complex ways which we understand very little at present.

The standard procedure for constructing theories or models in science is to collect data on the basis of controlled experiments, to hypothesise about the structure, function and dynamics of underlying machinery that could account for these data, and then to perform further controlled experiments to test these hypotheses in various ways. Unfortunately, such standard procedures are unavailable for our use in the study of language behaviour. Language behaviour is exhibited only by human beings and it is not possible to perform on them cortical ablation experiments of the kind that neurophysiologists have been performing on animals to study brain structures that underlie behaviour in the various modalities. [See Dr. Siddiqi's article (pp. 15–27) for descriptions of such experiments.] We have to base our studies exclusively on brain disorders that occur naturally, or on brain damages that are accidentally produced, for example, due to head injuries in war. In the last 100 years, a very large amount of data bearing on language behaviour has been collected from such studies. I shall try to briefly summarise here our present state of knowledge in this area. Unfortunately, this knowledge does not give rise to any coherent picture of the neural mechanisms that underlie our ability to use and understand language

Language disorders

"Aphasia" is a generic term used to describe language disorders of many kinds. Language disorders must have been known and observed for a long time But it was only in 1861 that Paul Broca presented to the Anatomical Society of Paris two cases of elderly persons with loss of speech and surmised for the first time that their speech deficiency was due to cerebral injury to a specific region in the left frontal lobe This region is now conventionally designated as Broca's area. In 1874 Carl Wernicke, a clinical neurologist working in Breslau, published a monograph on aphasia at the age of 26 with the title, "The Symptomcomplex of Aphasia: A Psychological Study on an Anatomical Basis". In this work he identified a second region in the cortex (which is now conventionally referred to as Wernicke's area) injuries to which gave rise to language disorders of a kind different from those that Broca had described. Wernicke referred to this variety as 'Sensory Aphasia' and distinguished it from the 'Motor Aphasia' of Broca. Wernicke's work is of great historical importance because it started a new trend in the study of aphasia: "a clinical-neurological approach in which an attempt was made to relate the patterning of symptoms of speech disturbance to the location of lesions in the brain". In the succeeding decades, Wernicke's students and followers made 'diagram-making' (of the brain) into an industry, inevitably generating a back-lash of criticism and antagonism to this approach. Hughlings Jackson (later 19th century) and his student Henry Head (early 20th century) in England, Marie in France, Freud, and others in more recent times like Goldstein, were vocal critics of the diagram-making approach and argued for a more holistic framework. Nevertheless there are eminent clinical neurologists who continue to espouse Wernicke's theoretical ideas; Norman Geschwind is perhaps the most persuasive of these.

In the 100 years since Broca and Wernicke, an enormous literature has accumulated on aphasia. Neurologists, neuro-psychologists, anatomists, physiologists, clinical psychologists, linguists, psycholinguists, have all had their say, have attempted to classify aphasia into various categories, and have tried to theorise about them. In the last two decades, several interdisciplinary conferences have been organised bringing together all these specialists in the hope that a coherent picture of aphasia could be drawn out of their separate studies Writing in 1890, William James expressed this hope: "Meanwhile few things show more beautifully than the history of our knowledge of aphasia how the sagacity and patience of many banded workers are in time certain to analyse the darkest confusion into an orderly display". Alas, a hundred years of patient work by 'many banded workers' has not yet begun to dispel our 'darkest confusion'.

After going through many of these interdisciplinary discussions and published papers, I find that, perhaps, the simplest way of summarising the generally prevailing views on aphasia is to relate them to the hypothetical automaton design that I outlined at the start of this article. That design, you may recall, called for a concept mechanism coupled to a speech analyser at one end and a speech generator at the other end This, then, gives rise to four functional interfaces (1) going from the acoustic signal to speech analysis, (2) the coupling between the output of the speech analyser and the concept mechanism (3) the coupling between the concept mechanism and the input to the speech generator and (4) going from the speech generator to the articulation mechanisms of speech

These four interfaces can give rise to four broad categories of disorders The first of these is really concerned with the hearing mechanism and is not specific to language behaviour So we shall not deal with it any more here The fourth category of disorder is called *Dysarthria* or *anarthria* and shows up as a difficulty in the voicing of speech In this sense this too, is not strictly a language disorder

The other two are truly language disorders the second corresponding to Wernicke's sensory aphasia sometimes called decoding disorder But it is perhaps more accurate to refer to this class as *receptive disorders* The third corresponds to Broca's motor aphasia sometimes called encoding disorder Again this class is best referred to as *expressive disorders* Published literature subdivides these two classes into a variety of more specialised categories But it is really very difficult to justify these subclassifications on convincing analytical grounds Attempts to relate them to injuries to specific areas of the cortex have not found general acceptance I shall now briefly describe the behavioural aspects of the language disorders belonging to these two broad classes More detailed accounts may be found, for example, in the book by Penfield and Roberts, or in Lenneberg's book *Biological Foundations of Language* There is also a detailed review report by Osgood and Miron which contains an extensive bibliography and details of clinical tests used in aphasia studies

Receptive Disorders The patient exhibits a marked inability to recognise or make sense of spoken language This is not due to lack of attention or deficiency in hearing The patient clearly realises that he is being spoken to and is expected to respond But he finds he is unable to make sense of the speech sounds he hears Somewhat paradoxically, although the patient may spontaneously use certain words and phrases he may not be able to repeat them on command or respond to them

Expressive Disorders The ability to respond in the language modality may be disrupted in many distinct ways

(*i*) Fluency of speech may be severely affected Patients typically respond in a style that may be called 'telegraphese' The following example illustrates this well "Mary, my Mary, yes Saturday, Cleveland wedding yes, married tomorrow, sometime, Sunday home, four days "

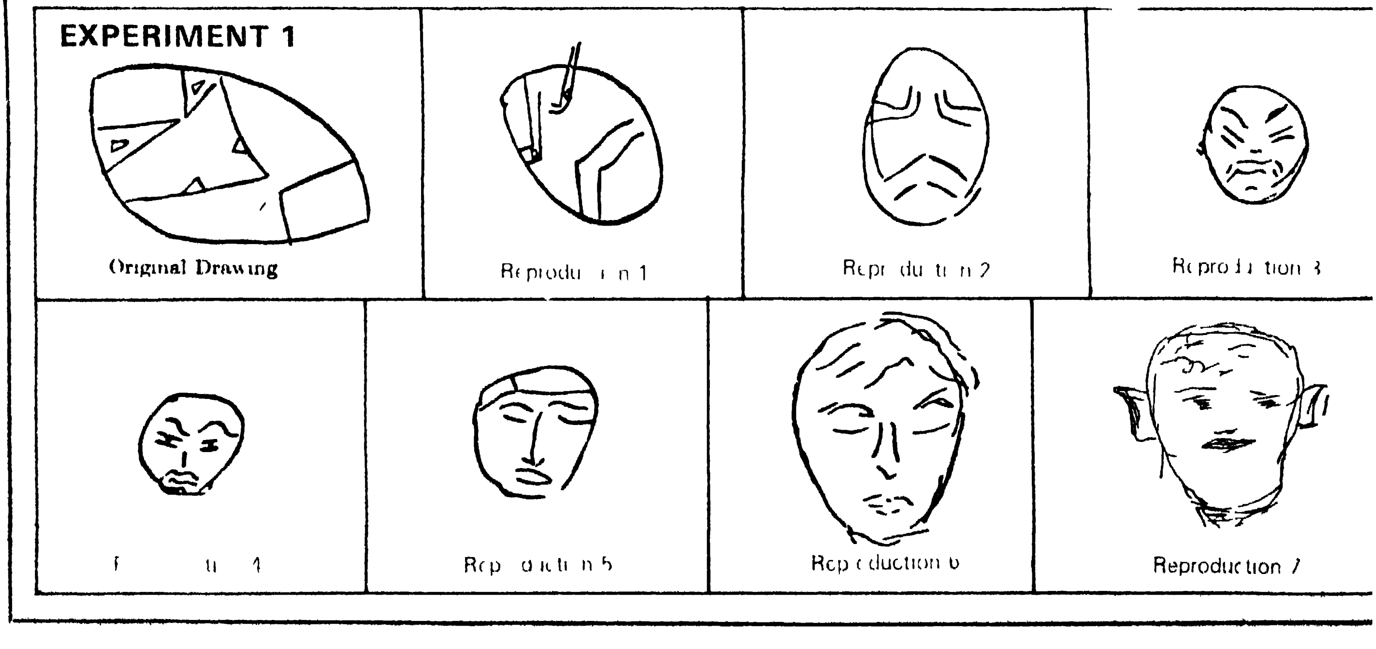
(*ii*) The flow of speech may be excessive and uncontrollable Linguistic expressions tumble out in a continuous stream and do not conform to any grammatical rules or accepted social norms "The patient jumps from thought to thought and topic to topic usually the substance of the communication cannot be understood"

(*iii*) Language usage may be disrupted in linguistically more significant ways For example, there may be an inability to name colours or numbers Naming of objects may be difficult or impossible As an example, a patient, when shown a knife and asked for its name, said 'that's a bilk a bite yes, meat bite' Quite often a patient is unable to find a word, but attempts to express himself in a roundabout way Unable to name a watch, he may say used to tell time Paradoxically again the same patient may quite spontaneously use the word watch by demanding Give me back my watch!'

Fig 3 These pictures illustrate the outcomes of two experiments in serial reproduction (see text for definition) that Bartlett conducted using picture material instead of prose texts Bartlett comments Whenever material visually presented purports to be representative of some common object but contains certain features which are unfamiliar in the community to which the material is introduced these features invariably suffer transformation in the direction of the familiar This constitutes a kind of analogue in the case of picture material to rationalisation in the case of the prose passages

In the first series (below) all the characteristics of the original which have any peculiarity are lost The face is made vertical becomes oval then round acquires eyes a nose and a mouth all of conventional form

The original of the second series (right) is a representation of the Egyptian *mulak* a conventionalised form of an owl It can be seen how accidental errors in recall tend to get progressively rationalised into deliberate details of the picture which are then simplified into conventionalised forms An owl thus gets transformed into a cat in successive steps!



There are other forms of linguistic disturbances which are sometimes referred to as *jargon* aphasia or *agrammatisms*. The following examples illustrate these varieties of disorders: " He is speeching it, there and then, straightaway for me, there ", " that I shall have lesson with the lungage of the hear itself ", " Well, I thought thing I am going to the tell is about my operation and it is not about all I can tell is about the preparation the had was always the "

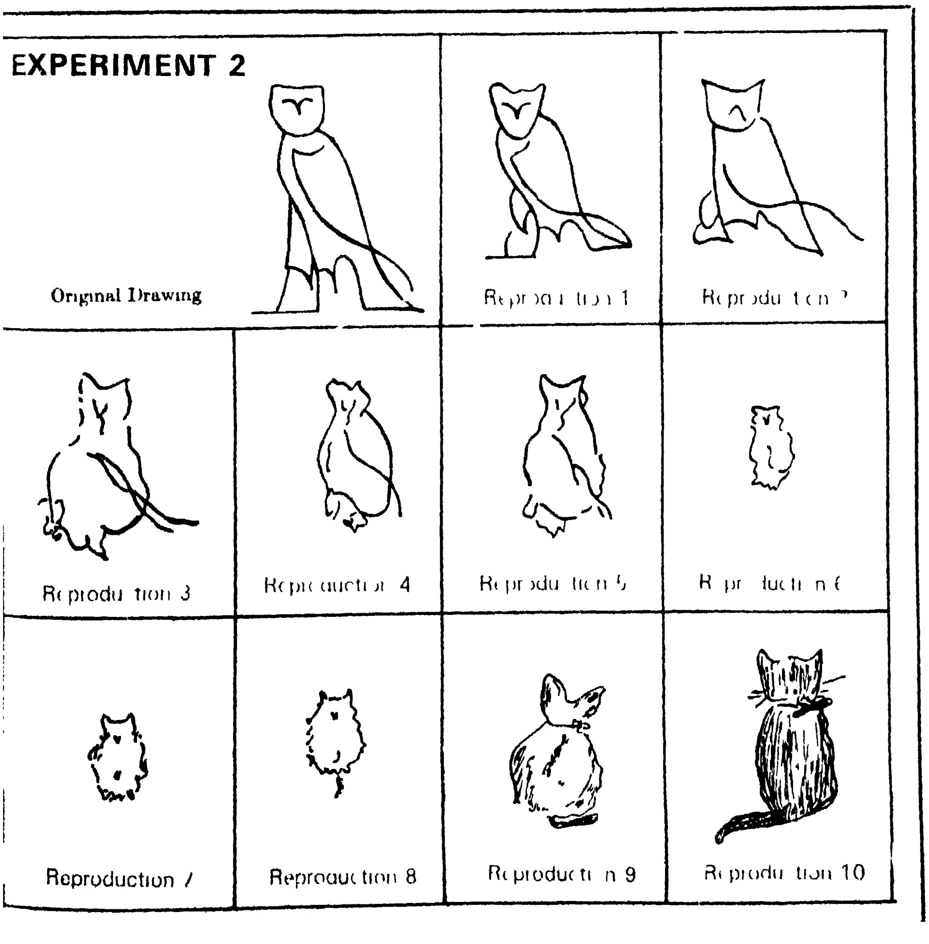
Closely related to aphasia are reading difficulties (*alexia*) and writing difficulties (*agraphia*) There is a vast literature on these ailments also But it would take us too far outside the scope of this article to go into the details of these

In a recent interdisciplinary conference on aphasia, an American clinical psychologist, Davis Howes, made the following point which I think summarises well the current state of affairs in aphasia studies He said, "Aphasia is often considered from three rather distinct aspects or levels the anatomical, the physiological, and the behavioural or psychological The extent to which there is agreement on our current knowledge of aphasia seems to differ very much at each of these three levels It would clarify matters considerably if we were to recognise **that the three levels at which we discuss aphasia are really not cognate** Our knowledge of aphasia comes exclusively from the first and the third the physiological is strictly an inferred level The confused picture of aphasia that one finds at this level thus signifies that we have as yet no satisfactory *theory* of aphasia "

Before we leave the topic of aphasia perhaps we should emphasise that the disorders we have been describing do not imply a " loss " of language As Lenneberg notes " The patient is not reduced to a state of no language he knows basically ' how language works ' Neither discrete words nor discrete grammatical rules are neatly eliminated from the store of skills but some physiological processes relating to activating, monitoring or processing of speech are deranged '

Remembering and recalling

In a companion article in this issue (pp 35 41), Dr Ramani discusses some aspects of short-term memory and attempts that psychologists have made to model the short-term memory processes To complement his discussions I shall consider here some of the long-term aspects of memory that psychological studies have brought out



To begin with, I should reiterate a point that Dr Ramani makes in his article One of the primary problems we face in dealing with memory is that we do not yet have a satisfactory language in which we can talk about behavioural phenomena associated with memory Our commonsensical ways of referring to memory processes are quite misleading For example, we tend to look upon ' remembering ' and ' recall ' as somewhat analogous to ' storage ' and ' retrieval ' In a real, physical world we may store information in a book, on computer tapes, in computer memory (or storage), or, we may store material items in cabinets, we may store letters in pigeon-holes Retrieval, then, is the reverse process We go searching for an item when in need of it, find where it is stored and retrieve it But, as we shall see presently, remembering and recalling are not processes of these kinds at all

' Remembering ' construed as ' storage ' raises, also, other much deeper issues We remember our experiences, we remember a picture, a face, a piece of music, we remember a word, a name, a variety of language expressions, we remember rules and procedures for solving problems or specific puzzles In each of these cases, what is it that is stored? In remembering a face, is it something like a photograph of the face that is stored? As the American psychologist Skinner remarks somewhere supposing this were true, it would not, in fact, solve our basic problem, but raise fresh ones For, now, we must worry about *who* looks at this photograph stored inside the brain and interprets it, draws inferences from it, and so on There is now much less of the brain available to do all these!

In the case of language, are individual words and expressions stored in some form? As in a dictionary, for example? Is there only a single entry for a given word, or are there multiple entries? Would it be possible to destroy selectively specific entries, like tearing a page off a dictionary, or destroying a letter in a pigeon-hole? Would that destroy one's capacity to use the particular word or expression, or understand it? We have already seen earlier, in our discussion on aphasia, that highly specific deficiencies of these kinds do not occur In fact, Penfield asserts that in his brain stimulation studies, " We have found no pigeon-holes in the cortex where words are sorted out Small removals may be made even in the cortex of the posterior speech area, and small injuries may occur there, with eventual recovery after aphasia And when command of speech returns to the individual, there is no special group of words to be learned over again, as would be the case if the pigeon-holes existed ". Dr. Siddiqi discusses in his article other equally unsuccessful attempts to locate specific memory traces in the cortex. All these negative results are highly counterintuitive and puzzling, for it is difficult for us to understand how highly complex symbolic activities can be learned and retained in the absence of very particularised internal representations of these symbolic details. And if they are to be there, what is the alphabet that is used for building up and preserving these internal representations? Quite clearly, either we are asking the wrong sorts of questions, or there are fundamental gaps in our understanding of the processes and mechanisms that underlie remembering and recall.

As in the case of studies on aphasia, although we do not yet have the rudiments of a viable physiological theory, at the behavioural level a considerable amount of verifiable data has been accumulated concerning remembering and recall. A very readable account of these may be found in a paperback, *Memory*, by I. M. L. Hunter.

The one basic conclusion that emerges from all the psychological studies in this area is that recalling does not consist of a simple *duplication* of some past event. It is a highly *selective and constructive* activity. One must not confuse recalling with reciting — reciting something that has been rote-memorised. For example, reciting a poem or a *sloka*, a postal address or a telephone number. Rote-memorising is simply the formation of a chain of stimulus-response associations for the most part. " It is a habit of the vocal machinery, learned through repeated trials (rehearsals) according to the laws of habit formation ". However, even in these cases two successive recitations by the same person are seldom exact copies of each other. Although the text may be faithfully reproduced in each case, there are likely to be significant variations in rendering, in intonation, rhythm, etc.

But recall of a past experience, a story we may have heard or read, or other factual details we may have been exposed to, is always a constructive activity. It is not like going to a cabinet and pulling out a stored item. The constructive nature of the activity may consist in the methodology of recall, or in the content of the recalled output, or in both, in general. As Hunter notes, even in such a simple act as recalling a person's name which is not readily available for recall one may go through complex procedures. " In attempting to achieve recall, we may be aware of some of the name's characteristics, for example, its rhythm or its length, or its first letter, or that it savours of some particular nationality, or that it is the same as that of some famous artist. . . ."

An interesting and simple experiment to try is this: take some fable, or a prose passage, or a news story, and ask a person to read it two or three times rapidly. Then, after an interval (during which time the person is kept occupied in some other task) ask the person to recall the passage as faithfully as possible. Get him to recall the piece again the next day, after several days, several weeks, months, and years, if possible. Now, compare the structures and contents of the series of recalled outputs. A variant of this experiment is the following: instead of asking the same person to recall repeatedly, give the output of the first person's recall to a second person, the output of the second person's to a third, and so on, to build up a series. Again make the same kind of comparisons of these outputs as in the first experiment.

Experiments in repeated recalls of these types were pioneered by the British psychologist F. C. Bartlett. He published in 1932 the results of his studies in a book called *Remembering* which has since then acquired the status of a classic in psychological literature. His findings have been replicated by others subsequently. Bartlett called these two types of experiments, the method of repeated reproduction, and the method of serial reproduction. In addition to using language specimens, he also tried these experiments using pictures and obtained analogous results (see Fig. 3, pp. 30-31).

Bartlett summarised his findings as follows. Literal recall hardly ever takes place. Almost always changes in the input material are introduced at recall. These may consist of both omissions and additions. The changes introduced are not arbitrary but occur in such a way that the material is conventionalised and rationalised. Both these transformations are carried out in conformity with the cognitive patterns common to the social milieu to which the individual belongs. The results of these transformations render the material easier to handle and to recall. In both kinds of experiments, these transformations reach a stable state after which recall takes place without further significant alterations.

To illustrate the kind of changes that take place, consider the following fragments taken from one of Bartlett's experiments in serial reproduction. The fragment is from the end of the text used in the experiment which is called " The War of the Ghosts ".

Original: When the Sun rose he fell down. Something black came out of his mouth. His face became contorted.

Serially reproduced outputs:

1. When the Sun rose he fell down. And he gave a cry, and as he opened his mouth a black thing rushed from it.
2. When the Sun rose he suddenly felt faint, and when he would have risen he fell down, and a black thing rushed out of his mouth.
3. He felt no pain until sunrise the next day, when, on trying to rise, a great black thing flew out of his mouth.
4. He lived that night, and the next day, but at sunset his soul fled black from his mouth.
5. He lived through the night and the following day, but at sunset his soul fled black from his mouth.
6. He lived during the night and the next day, but died at sunset, and his soul passed out from his mouth.
7. Before the boat got clear of the conflict the Indian died, and his spirit fled.
8. Before he could be carried back to his boat, his spirit had left this world.
9. His spirit left the world.
10. (" Nonsense " said one of the others, " you will not die.") But he did.

Bartlett comments: " The changes come gradually, but the end is foreshadowed from the beginning. First the ' something black ' gains a kind of force or vivacity of its own: ' it rushed out '; then ' it flew out '. Then the activity receives explanation, for the black thing becomes the man's soul, and, by a common conventional phrase, it is said to have ' passed out ' . . . . Convention comes in again and the phrase changes to ' his spirit fled ', and eventually to the commonplace and everyday: ' his spirit left the world '. Then this phrase also goes the way of the others and there is nothing left except the statement that the man died. . . . The total effect (of the changes) is to make the whole incident ordinary and rational. But no one of the subjects worked with the knowledge of the thing he was doing."

The relevance of these findings to what happens when stories circulate or are handed down from generation to generation, should be obvious. I refer you to the book by Hunter for interesting discussions on these points.

It would take too much space to deal with all aspects of remembering and recall. Clearly, recall is closely related to recognition. There is much behavioural data available on recognition. Recognition is easier to accomplish than recall as anybody who has experience of answering examinations based on open-ended questions and multiple-choice questions knows. Another closely related topic is 'forgetting'. Are items once available for recall always available for recall?

Earlier I raised the issue of remembering faces. Despite my remarks there about 'photographic' memory, it has been found that certain persons, very young children especially, possess a highly remarkable form of visual memory which, for all practical purposes, behaves like a photographic memory. This is called *eidetic* imagery and has been extensively studied although the physiological basis for this is very little understood. You should be able to [illegible] details on all these topics [illegible] book on psychology.

But there is one la[illegible] say something abo[illegible] And this relates to [illegible] ing o[illegible] memory. [illegible] to be thou[illegible] and is, pe[illegible] still believe[illegible] — th[illegible] memory can be s[illegible] by *exer*[illegible] one[illegible] exe[illegible] Jam[illegible] an[illegible] m a book en[illegible] *the M*[illegible] by [illegible] olbrook [illegible] Yo[illegible] tre[illegible] memory i[illegible] p[illegible] the [illegible] da[illegible] the eve[illegible] is [illegible] . . . He is a[illegible] all the facts and [illegible] again in the [illegible] en[illegible] om any [illegible] co[illegible]

into the mechanical, the judicious, and the ingenious. The mechanical methods consist in the intensification, prolongation and *repetition* of the impression to be remembered. . . . Judicious methods . . . are nothing but logical ways of conceiving them and working them into rational systems, classifying them, analysing into parts, etc, etc. All the sciences are such methods." Ingenious methods are the ones based on specially designed mnemonic codes of various degrees of complexity. All mnemonic codes are based on associative mediations. In this sense they are directly related to classical conditioning techniques. [See Dr. Siddiqi's article for details on conditioning.]

The account that I have given of memory and language behaviour in this article is necessarily [illegible] and inadequate. But I hope this brief outline brings out force[illegible] the vast gaps in our understand[illegible] of the brain mechanisms that support complex symbolic behaviour such as our use of language. As I have been emphasising repeatedly, we seem to [illegible] an appropriate language even to formulate our problem in. Our everyday linguistic conventions lead [illegible] talk about the operations of our [illegible] if they were the results of the actions" of an autonomous agent dwelling inside us. Clearly this is a [illegible] metaphor. On the other hand, [illegible] ence, as in other spheres, we have [illegible] use of analogies in the beginning stages if we want to make any way [illegible] all. Our dilemma is that [illegible] do [illegible] yet have a serviceable analogy.

Pro[illegible] J. Z. Young of the London Univ[illegible], in the Reith lectures that [illegible] ver the BBC in 1950, made [illegible] y interesting observations [illegible] use of analogy in the study [illegible] and behaviour at various [illegible] n the history of the development [illegible] this subject. Descartes, who [illegible] t a time when the design of [illegible] ork automata had reached a [illegible] level of sophistication, argued [illegible] animals were automata of this [illegible] nd. Later, when telephone exchanges were invented, it seemed natural to compare the brain to a complex switchboard. More recently, computer technology has provided its own specialised inventory of terms, such as software, buffers, subroutines, and so [illegible] But, as I pointed out earlier, [illegible] paring our memory to a storage [illegible] e, in the sense this is understood [illegible] puter architecture, raises more [illegible] than it solves.

[illegible] asic problems we have to [illegible] rselves to are, determining what kind of information is stored ("retained" is probably a more neutral term) and how this information is *represented* internally. It is quite clear that a good deal of our knowledge is skill-based. In such cases we can at least theoretically argue that the internal representation must be in terms of the action sequences (or complexes) that enable us to exercise these skills. Although I personally tend to believe that a good part of our memory is based on our action mechanisms, it is difficult to account for everything in these terms. For example, what mechanisms could we invoke to account for eidetic imagery?

One aspect of the physiological system I have not referred to at all is the part that underlies our affective and emotional states. It is well known that these states play a fundamental role in determining our behaviour — in determining what we perceive, how we perceive, what we learn, how we perform intellectually, and so on. The functioning of memory — remembering, recalling, forgetting, recognising — must clearly be decisively determined by this part of the physiological system Although a large amount of behavioural data exists concerning these aspects, again, we do not have the rudiments of a coherent picture of how the total system functions.

Let me close by drawing attention to the fact that, although we know much about the mechanisms that give rise to the observed behaviour of the Sun and stars, our understanding of our own behaviour is pitiably fragmentary To quote Professor Young: "The study of the brain is certainly one of the most challenging of all scientific problems. At present we spend much of our mathematical and physical genius on the study of the world around us. Why not apply more of it to ourselves and especially to our brains?"

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MEMORY AND 'TRUTH DRUGS'

During World War II, the German Gestapo was said to have used some form of "truth drugs" to make captured resistance fighters confess or reveal secrets they otherwise wouldn't even under extreme torture (Remember Alistair McLean's *Guns of Navarone*?). The drug was believed to be scopolamine, one of the narcotic alkaloids (the others are hyoscyamine, atropine and polandrene) of plants like Mandrake root, nightshade, belladonna, henbane and Jimson weed — all belonging to the family *Solanaceae*. Incidentally, these plants have been known since ancient times for their 'awesome' powers to alter perceptions, ideas and emotions.

Psychiatrists sometimes use hypnotic drugs in narcoanalysis — to stimulate patients' talk. There are some forms of psychiatric disorders — Sigmund Freud was the first to call it 'repressing' — in which there is "an unconscious blocking of recall of certain experiences which have the potentiality of causing the person pain". There is very scattered published literature on narcoanalysis. The best overview, perhaps, is contained in Lawrence Z. Freedman's article "Truth Drugs" in *Scientific American*, March 1960. (The term 'truth drugs' derives from the popular belief that they "chip away the conscious control of behaviour and lay bare the truth".)

Freedman has cited the investigations of Humphrey Davy into the effects of nitrous oxide (laughing gas) at the close of the 18th century. Davy had persuaded Coleridge, Robert Southey and others like Roget (of the *Thesaurus* fame) to record their sensations on inhaling nitrous oxide. He himself wrote: "I gradually began to lose the perception of external things, and a vivid and intense recollection of some former experiences passed through my mind, so that I called out, 'What a concatenation of ideas!'"

Davy had noted that the physical and mental effects of the gas varied among individuals, their temperament and mood. Davy's observations went unnoticed. Years later, William James was to pick up the idea, though: "Our normal waking consciousness as we call it is but one special type of consciousness, whilst all about it, parted from it by the filmiest of screens, there are potential forms of consciousness entirely different. We may go through life without suspecting their existence; but apply the requisite stimulus, and at a touch they are there."

The first psychiatric use of such drugs came accidentally in 1916 at the University of Wisconsin where Arthur S. Loevenhart and colleagues were experimenting with respiratory stimulants on catatonic patients. One patient, for long rigid and mute, suddenly relaxed and opened his eyes after an injection of sodium cyanide; he even answered a few questions. Later, at the Massachusetts General Hospital, Erich Lindemann established that the drugs, most probably, removed certain psychic inhibitors and thus brought about verbal release. Modern studies have shown that the drugs affect the higher brain centres generally — those regions of the cerebral cortex that are usually thought to be of the most recent evolutionary development and are engaged in higher associative and behaviour-organising functions — the cause is a diminution in the brain-tissue metabolism brought about by the drug. Larger doses, in turn, depress the functions of the next lower centres. However, the action depends on the personality, tolerance level and environmental stimuli.

Early in the century, physicians had used scopolamine with morphine and chloroform to aid women in childbirth (to induce the 'twilight' state of sleep), and it was found that such women often volunteered very candid remarks. It was, however, the remarkable 1922 experiments of Dr. Robert House of Dallas in Texas involving the use of scopolamine in interrogating suspects in custody that brought this drug into the public eye. What was not so well publicised was that scopolamine had later been disqualified as a truth drug after the discovery of its several toxic side-effects. (Incidentally, scopolamine is more commonly known as hyoscine.)

Scopolamine's place has been taken over by sodium amytal and sodium pentothal. Sodium pentothal was used in narcoanalysis of emotional casualties during World War II and the Korean War. It must be mentioned here that though law courts do not admit evidence obtained by involuntary examination under drug, the chemicals are still being used in some places in pre-trial investigation.

Freedman has pointed out that the popular misconceptions about 'truth drugs' arise from the ignorance about what the drugs seek to elicit: "The psychiatrist is not interested in establishing the truth in any probative sense. In the development of psychological reality . . . the patient's account of his fantasies and delusions is as significant as his reliable recollection of past events. Drugs may be helpful to the extent that they provide a 'psychological analgesic', a relief from the inhibition of anxiety and guilt that blocks communication with the physician".

And talking about fantasies, there is the remarkable work by Frederick C. Redlich and Leonard J. Ravity Jr. of the Yale University using sodium amytal: on the one hand, they found, strong-willed normal people could maintain a lie (like an invented self-defensive story) even under the drug; on the other hand, neurotics with strong unconscious self-punitive tendencies not only tended to confess more easily but also to substitute fantasy for the truth, confessing to offences never actually committed.

P. P.

Models of Memory

S. RAMANI

> *"The stream of thought flows on; but most of its segments fall into the bottomless abyss of oblivion. Of some, no memory survives the instant of their passage. Of others, it is confined to a few moments, hours or days. Others, again, leave vestiges which are indestructible, and by means of which they may be recalled as long as life endures. Can we explain these differences?"*
>
> · William James in *The Principles of Psychology*, Vol. I

The problem with words like 'memory' is that they refer to a variety of complex phenomena and, by giving them all a common and simple label, they mislead you into looking for a neat explanation that explains everything. However, recent investigations have, usually, taken into account the diversity and complexity of memory-related processes. We will now look at a small set of questions that have been asked, and partly answered, by psychologists over the past decade or two. They do not exhaust what is known, but they do give us some idea of the variety of questions that psychology asks and answers in an increasingly satisfactory manner.

The questions

The simplest differentiation of memory is in terms of the time element — short-term memory (STM) and long-term memory (LTM) being very commonly used phrases in the literature. Visualise a cashier in a bank counting a wad of currency notes. The memory that helps him keep track of the steadily increasing count need not be made of the same "fabric" as the memory he has of a friend whom he has not met in the last ten years.

Another dimension is that of sensory origin. Do things seen and sounds heard go through the same pathway? Once perceptions enter memory, do they lose their sensory links, or does the memory of something heard differ in nature from the memory of something seen?

Then there are questions of processes in memory. Let us take an example. Do you know of anyone who wears a tie regularly? How did you arrive at this answer?

Did the idea of tie-wearing instantly trigger off this person's name?

- Or did the names of a number of persons pass through a test procedure in your mind till one of them got selected?
- Are you aware of any person who was rejected by such a process as one who does not wear ties?
- Did you end up with two or three tie-wearers even though you wanted to name only one?
- Assuming that some search procedure did, in fact, go on in your mind, do you think that it could have gone on without your being aware of it?

If there are processes of the mind which operate on the " contents " of memory, what can we say about the nature of the " contents " themselves? Consider the following telegram.

APPEAR FOR INTERVIEW WITH OUR CONSULTANT AT OUR CENTRAL OFFICE IN NAGPUR NEXT FRIDAY

- What kind of structure will the data in this telegram fit into?
- Will the words of the telegram be remembered in sequence?
- Will the grammatical form be forgotten while the meaning gets captured by the long-term memory?
- Does any model of language predict the nature of success and failure experimental subjects will have in remembering various features of the telegraphic message, grammatical as well as semantic?

An interesting point about the questions raised here is that many of them could not have been asked a few decades earlier. The concepts necessary to frame and answer these questions search process models, appropriate structures for representing information, coding and transformations of information from one form to another, pathways and buffers — were not available in an earlier age.

Some of these concepts can be examined now by discussing a few of the questions raised above; of course, we do not promise an exhaustive set of answers.

A pathway for certain visual impressions

It has been known for nearly a hundred years that visual information is gained in short bursts. You may not realise it, but your eyes are making many quick movements every second: they take in information only during brief pauses between these movements, called saccades. The pauses are called fixations and they provide the eye with a rapid series of still pictures. It is, therefore, understandable that psychologists have investigated in detail the perception of images in brief exposures.

Fig. 1 Tachistoscope used by George Sperling to investigate short-term memory. For 1/20 of a second, arrays of letters (as shown in Fig. 2) are shown; the subject later reports the letters he remembers

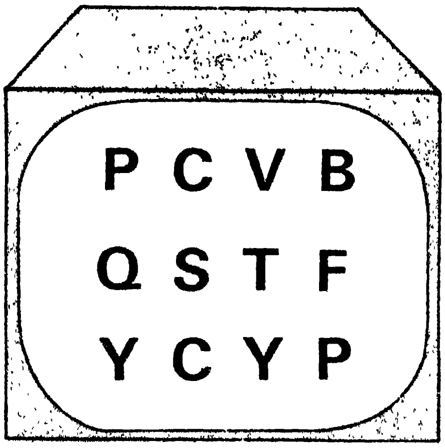


Fig 2 Typical visual stimulus, projected for 1/20 of a second preceded and followed by dark screen, to avoid interference from other images

A commonly used device is the tachistoscope which you can think of as a slide projector with a timed shutter of the type one finds in cameras (Fig. 1). Investigations in this area normally involve the presentation of a picture (Fig. 2) containing a number of letters for a very brief period to human subjects, who have to report the letters they see. The average number of letters correctly recalled varies from four to five. The duration of the flash which projects the image is usually in the range from one-hundredth of a second to half a second.

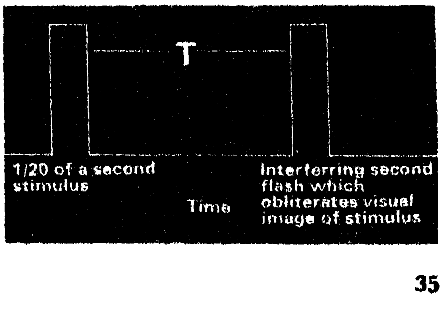
Initial experiments of this type were conducted 80 or 90 years ago. Recent work in this area was pioneered by George Sperling, who threw considerable light on the way information is processed in this task. Sperling started with a couple of important observations:

- Subjects reported that they noticed the presence of many letters even though they could recall only four or five correctly
- Subjects could report (four to five) letters correctly even after several seconds of waiting following the stimulus presentation.

The question now was about the presence of a visual information store (VIS), or visual memory, which by itself could explain the outcome of these experiments (Fig. 4). Sperling repeated, with certain refinements, the experiments originally carried out by Baxt (around 1871), in Helmholtz's laboratory, to investigate this model. These experiments involve a second stimulus presented after a controlled time (T in Fig 3) following the original stimulus. As long as T exceeds 0·1 second, the second stimulus does not affect the number of letters recalled from the first stimulus.

If the model shown in Fig 4 is to be believed, there is only one information store The second flash, following the stimulus after a delay of 0·1 second, would disturb the contents of this store. How does the subject hold on to the stimulus for several seconds? Clearly, one can rule out this model on this ground. There is a need for a second information store in which information on stimulus letters can be held without being destroyed by the second flash.

Fig. 3 Time sequence of events for investigating the nature of visual memory As long as T exceeds 0·1 second, the subject's recall of letters in the original stimulus is not affected by the second flash


T
1/20 of a second stimulus
Time
Interfering second flash which obliterates visual image of stimulus

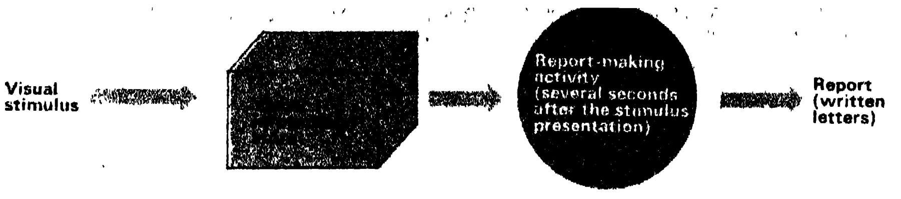

Visual stimulus
Report-making activity (several seconds after the stimulus presentation)
Report (written letters)

Fig. 4 Model based only on visual memory

There is good evidence to believe that the second store involved in the behaviour being discussed is an auditory information store (AIS). Even though the recalled letters are reported in writing, the subjects make mistakes which betray the involvement of an auditory store. Seeing D and reporting T or seeing 2 and reporting T are examples of such mistakes. If they see 2 and report Z, one would ascribe this to confusion between visually similar symbols, but T and D or T and 2 are alike only in terms of sound.

The AIS would, of course, explain the ability of a subject to give a report several seconds after the stimulus, even after the contents of the VIS have been disturbed by a second visual stimulus.

Information given in the spoken form can be remembered for several seconds. The fact that subjects who have to remember a list of symbols frequently speak out its contents (silently or aloud) to themselves is well known. This is called rehearsal. Fig. 5 shows how rehearsal can feed back to an AIS its own contents. Suppose contents of an AIS decay over a few seconds when left alone. Rehearsal can be used to increase the time over which the memory is kept alive by this AIS.

In experiments of the type Sperling conducted, one can try to disturb the subject's memory by playing a recorded voice which calls out a series of digits not connected with the symbols shown visually. Since the subject's task is to remember what he has seen and to report it, the irrelevant speech signal acts as a disturbing agent. It causes a small but definite decrease in the number of symbols the subject can remember (and report) out of those he has seen. Further, the disturbing speech signal often forces subjects to mumble to themselves (use rehearsal audible to an observer) what they have to remember. In this manner, they seem to be counteracting the effect of the disturbing sound. All this constitutes evidence in favour of the idea that an AIS is involved in remembering and reporting what is seen.

Speed mismatch: visual scanning and auditory rehearsal

The model of Fig. 5 is surely an improvement over the model of Fig. 4. But, it has its own weaknesses. By visual interference techniques (Fig. 3), it has been shown that the information in the VIS is moved out at the rate of one letter (or symbol) every one-hundredth of a second. But the AIS does not seem to accept input any faster than one letter for every one-sixth of a second.

Consider the model shown in Fig. 5 in the light of these transfer speeds. What does this model predict regarding the number of signals that can be remembered from a momentary visual presentation? Clearly, the number of symbols reported will be:

$$\left[\frac{\text{available transfer time (for moving from VIS to AIS) in seconds}}{6}\right]$$

This is because the AIS can accept only around six symbols per second.

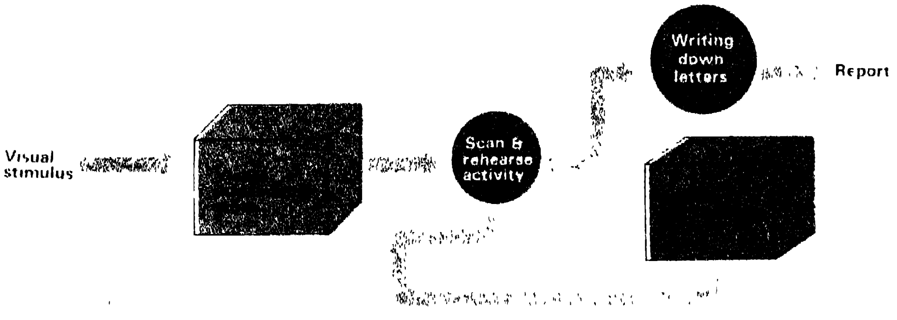


Fig 5 Model involving an 'auditory information store'

This prediction turns out to be wrong. Sperling showed that even when an image was left undisturbed only for 0·1 second in the VIS, the subject was able to report 4 or 5 symbols from those seen.

Sperling chose the model shown in Fig. 6 to explain this ability. This model contains a third information store called the recognition buffer to accept information at a rapid rate from the VIS and to keep it while the AIS accepts it at its own rate.

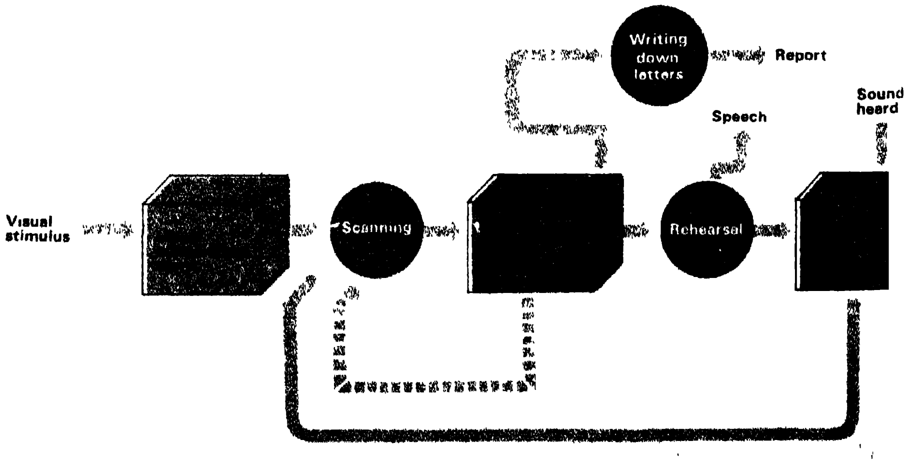


Fig. 6 Model incorporating three stores

Capacity of the VIS

One of the interesting outcomes of Sperling's work was an estimate of the capacity of the VIS, which turned out to be larger than expected. We know that the subject in his experiments generally reported only 4 or 5 symbols. What was the main cause of the limit? Was it due to the limited capacity of the VIS, or limited capacity of the AIS, or was it due to the speed with which information in the VIS can be processed before its contents decayed or were disturbed? Sperling showed that the capacity of the VIS was not the limit. In one of his experiments, he projected three rows of symbols (Fig. 2). The projection lasted 1/20th of a second. Following this, he would sound a tone, well after the projection ended, to indicate which row of signals the subject should report. The delay between the projection and the tone was varied from 0·1 second to 1 second in different experiments. The subject was to report the top, middle or bottom row, depending upon a high-pitched, medium, or low-pitched tone being heard.

It turned out that the subject could report the chosen row without difficulty, indicating that the VIS is large enough to keep all the symbols (around 12) for a fraction of a second, unless the VIS is disturbed by new input. Similarly, one can show that the AIS itself has a capacity larger

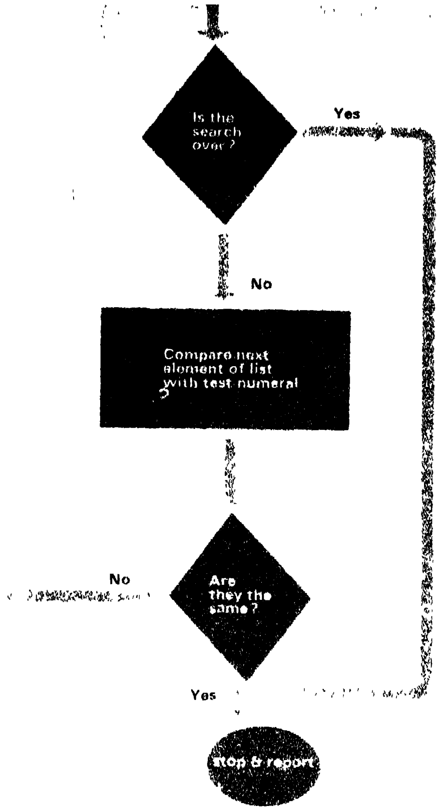


Fig. 7 Serial search of short-term memory

than the number of symbols the subject reports in Sperling's experiments (4 or 5). This leads to the belief that the limit to the number of symbols reported is due to the low processing rate beyond the VIS. Information handling beyond the VIS takes a definite time for each symbol being reported. While this processing is going on, the information in the VIS is decaying. The rate of processing is such that only 4 or 5 symbols can be 'grabbed' by later stages before they decay. That the capacity of the VIS is large is shown by the fact that as many as twelve symbols can be stored in it, and any four of them 'grabbed' on the receipt of a tone signal which arrives after the projected image has disappeared.

Sperling's experiments probed the nature of stores or buffers that are involved in remembering visually presented information. An interesting fact is that in models of the type considered by Sperling (Figs. 4 to 6), almost equal importance is given to processes, the circles, as to the stores, the cubes. It is possible to identify specific processes and to probe into them in depth. A good example of an investigation of this type involves a search process.

Searching short-term memory

A set of experiments reported by Saul Sternberg deal in detail with the nature of search that is involved in the item recognition task.

It is essential at this stage that you read the box "The numeral recognition task" (right). You must take the test given in that box, and then read the description of Sternberg's varied-set procedure for this task.

By offering payments to volunteers for correct and quick responses and penalising errors, Sternberg got his subjects in the numeral recognition task to give correct answers 98 or 99 per cent of the time. He then set out to investigate the nature of the recognition process that enables subjects to identify a test numeral as one in the memorised list or one that is absent. He recorded the reaction time RT: the time between presentation of the test numeral and the response, lever-pressing. He found out how RT changed as one increased the difficulty of the task by increasing the length of the list to be memorised. He also examined if RT was different for positive responses (test numeral is in the memorised list) and for negative responses (not in the memorised list). Several other factors were also studied. Suppose the same list is used in one trial after another, so that it becomes more familiar than a list learnt for a specific trial. Does the RT change? (Briefly, the answer is, no, it does not). Suppose we use photographs of human faces instead of numerals. Does this change the experimental results significantly? (No, it does not.)

Models for the search process

Since the Sternberg experiments involved the study of many different factors, it is necessary to look into his results step by step: take the effect of a specific factor, take specific hypotheses, and then look at experiments relevant to these; examine the possible alternative models and see which ones are supported by the experiments.

One possibility is that comparison of the test numeral could occur simultaneously ('parallel search') with all the remembered numerals. If this is the case, reaction time (RT) will be the same irrespective of the number of numerals in the memorised list.

Alternately, comparison could be a 'serial search', as in Fig. 7. Such a serial search predicts that RT will increase with the length of the list, since a set of operations have to be repeated for each list element. Experiments showed such an increase:

No. of elements	RT (sec) (approx)
1	0·44
2	0 48
3	0·52
4	0·56
5	0·60
6	0·64

THE NUMERAL RECOGNITION TASK

(Take a pencil and paper before you start.)

You will be given a list of five numbers. Memorise it:

7
2
4
8
6

Have you read the list carefully?

You will now be given a set of numerals. Read each numeral, one at a time, and place a √ mark next to it if it is in this list memorised. Now, to get the test numerals, turn the page.

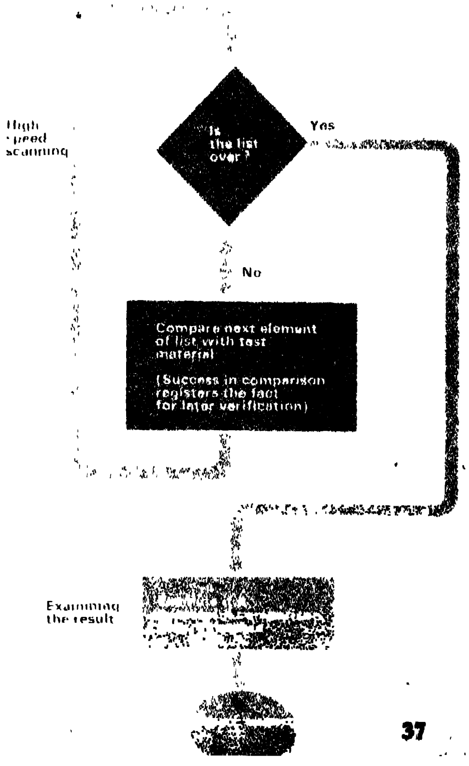
There seems to be a minimum RT of about 0·4 second which can be attributed to activities carried out only once, such as result-reporting.

Is the serial model satisfactory?

To investigate the model further, we can draw other verifiable inferences from it. For instance, will it take longer to recognise that the test numeral is in the list, or, will it take longer to say it is not there? Obtaining a successful match obviously terminates the process in Fig. 7, but failure to get a match can be reported only after scanning the completed list. So one would expect that a recognition will be reported after a shorter RT than a failure to recognise.

Secondly, what about the position of a recognised numeral in the list? Shouldn't one be quicker to recognise a numeral at the top of the list than one that occurs later on? Hence the

Fig. 8 The exhaustive serial search model


High speed scanning
Is the list over?
Yes
No
Compare next element of list with test material
(Success in comparison registers the fact for later verification)
Examining the result

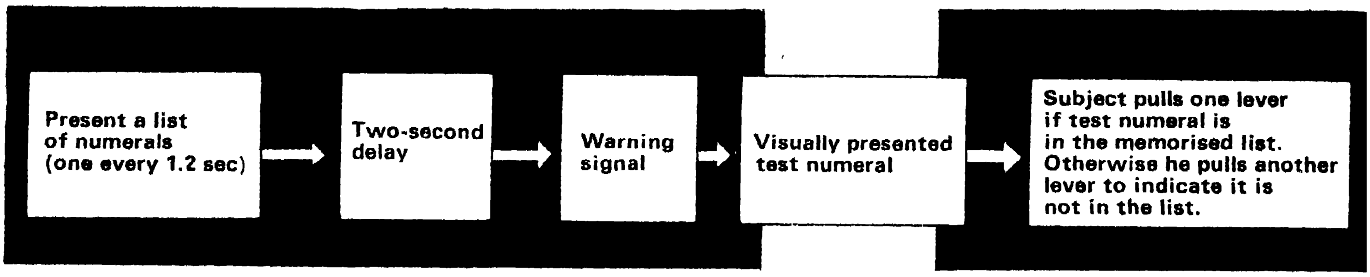
THE NUMERAL RECOGNITION TEST

Read the following, one at a time, marking each numeral with a √ if it is in the list memorised:

5
4
3
9
2

Sternberg's varied-set procedure for the numeral recognition task

This is very similar to the test you have taken just now (see above).


Present a list of numerals (one every 1.2 sec)
Two-second delay
Warning signal
Visually presented test numeral
Subject pulls one lever if test numeral is in the memorised list. Otherwise he pulls another lever to indicate it is not in the list.

The list of numerals used is changed before it can become part of the long-term memory.

model of Fig. 7 predicts a smaller RT for numerals earlier in the list.

Experiments failed to support these two predictions. Sternberg demonstrated convincingly that RT was the same for reports of recognition as for reports of failure in finding the given numeral in the list. He also showed that RT was reasonably independent of the position of the recognised numeral on the list. On the basis of these findings, he chose the exhaustive search model of Fig. 8. In this model, the search for recognition is a fast operation (scanning) which ends only when every element of the list has been compared with the test numeral. A match is recorded for later examination, but it does not stop the scanning. Sternberg theorised that examining the "match register" to make a decision (say, to continue the search, or to terminate it) was a time-consuming operation. Hence it is more economical to do it only once.

The scanning process is a fast operation: Sternberg's estimates indicate 25 comparisons per second are common.

The nature of items in the short-term memory

You would remember that George Sperling found that an STM in his model was an auditory information store (AIS). Even when the stimuli were visually presented, information on them was stored in the AIS. Now, we can ask if the STM involved in performing Sternberg's numeral recognition task is also an AIS You will remember that major support for the involvement of an AIS is often provided by indications that the subject 'rehearses', sometimes to the accompaniment of audible mumblings, and sometimes without audible sounds (sub-vocally). Experiments indicate that even sub-vocal rehearsals cannot be very fast, certainly not fast enough to examine each element of a list in 1/25th of a second, as demanded by the Sternberg models. So, he probed the nature of the STM involved. For this purpose, he used 'visually degraded' test numerals (Fig. 9) in the place of the clean or 'intact' numerals used earlier. The nature of change in RT due to the use of these degraded stimuli gives valuable evidence regarding the properties of the STM involved.

There are two possibilities:

(*i*) The memorised elements and the test numeral are represented in memory in an abstract form. Visual quality of presentations (intact or degraded) should not make a difference to the abstract form in which information is stored in the memory. Of course, there may be a fixed delay introduced in converting a test numeral which is visually degraded into the abstract form.

(*ii*) The representation of numerals in the memory is changed by visual quality of the presentation. In this case, the time taken for every comparison will change as a result of visual degradation of the test stimulus.

Let us consider the RT measured in experiments involving intact stimulus numerals. To this we can add predictions based on the two possibilities discussed above.

Length of memorised list	RT	RT1	RT2
1	·44	D+·44	·44+k
2	·48	D+·48	·48+2k
3	·52	D+·52	·52+3k
4	·56	D+·56	·56+4k
5	·60	D+·60	·60+5k
6	·64	D+·64	·64+6k

RT1 is the prediction made according to the possibility (*i*) above for degraded stimuli. RT2 is the prediction as per possibility (*ii*) above.

If abstract representations are used in comparisons, we should expect that RT will increase by a fixed amount irrespective of the length of the memorised list. On the other hand, if non-abstract representations are used RT will increase in a different manner when visually good inputs are replaced by visually degraded ones. The increase will be proportional to the length of the memorised list. Sternberg's experiments verified the prediction marked RT2 in the table above.

A part of the picture that emerges from Sternberg's work on the numeral recognition task can be described as follows:

(*i*) a short-term memory is involved in which information is not present in a pure or abstract form;

(*ii*) comparisons can be made with the contents of this STM at rates as high as 25 per second;

(*iii*) the fast comparison operation always runs to the end of the list, even when an element of the list matches the item being searched for;

(*iv*) lists of visually 'degraded' items are stored in such a manner that comparisons of these degraded items with a given item take a longer time than comparisons of 'intact' items.

Sperling's and Sternberg's experiments indicate the kind of questions that are profitable to ask about the STM and the type of experiments that give us answers to these questions. There are, of course, many other questions about the STM that we cannot deal with here in a few pages. But a couple of points are worth mentioning.

One is the question of our being conscious of different parts of our memory and their activities. Whatever is in the VIS gets lost and is never noticed unless it is taken up for further processing. That our memory for a visually degraded numeral takes more time in a comparison than the memory of an intact numeral was

never known to most of us. It becomes fairly clear from all this that we are unconscious of information processing going on in parts of our mind. Is this a disturbing idea? Is it more disturbing than the fact that one is unaware of the existence of, say, his liver and its functions till he is taught about it?

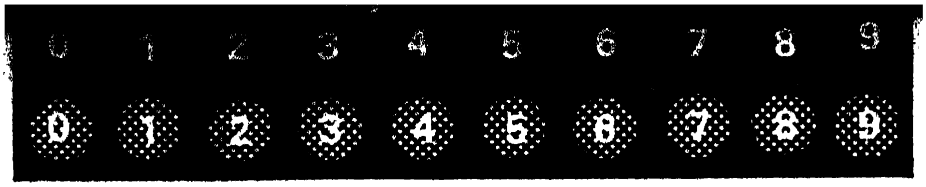


Fig. 9 Intact and degraded visual stimuli

The computer analogy

Another important point is the nature of limitations of the STM and their significance in human behaviour. Long-term human memory has a large capacity and searching for information in it possibly involves highly parallel operations. In contrast, the STM has a very limited capacity. In the middle of a problem-solving task, you are seriously limited by the capacity and the nature of the STM. Getting information into it and keeping necessary information from being displaced from it involve paying a price. The nature of mental activity we can carry out at reasonable speeds is very much constrained by these restrictions. Sternberg's finding that scanning in the STM is normally exhaustive (instead of being a self-terminating one) is a very important pointer in this direction.

We must compare the division of human memory into LTM and STM with the division of the information store in computers into a main memory and a set of registers. Most computers can store half a dozen or a dozen items of information in the registers and 1,00,000 items in the main memory. Registers provide an expensive short-term memory which speeds up work, but it has to be small in capacity to keep prices down. It is common for computer programs to use pointers to chunks of information in the main memory. A pointer is only one item of information, but it provides a link to a set of connected information items in a large memory. By using such pointers or ' associations ', computer programs smoothly move in relevant information chunks to the high-speed registers when needed.

Another interesting fact is that, most computers operate in a highly serial fashion as far as computing is concerned. The set of registers deal only with one problem at an instant and the computer is performing only one computation at any given instant even though users often get the feeling that a computer is doing many things simultaneously.

Neither the use of a small capacity STM nor the highly serial operation are necessary properties of every conceivable computer. One could not have predicted from a knowledge of the principles of computer design that the human mind should necessarily be limited in the capacity of the STM and in the number of operations it could be doing simultaneously. On the other hand, it is turning out to be the case that the human STM is quite small in capacity. Further, many of the activities involving the human STM are serial computations.

Why is this so? What can we say about these from reference to the computer analogy? There are advantages in having a single computation in progress in a computer involving the short-term memory. Any machine based on such a design would be much simpler than one which allows multiple computations to occur truly simultaneously.

Similarly, a computer design which involves a small-capacity high-speed store (naturally expensive) and a large-capacity low-speed store is a good design. We can surmise that this principle holds even in the case of the electrochemical machine that is so important to us. Fast access memory being more ' expensive ' in biological terms could explain the use of a two-level memory system. A small fast memory holds items immediately relevant to an on-going process. Material required for further work would be brought in from the larger, slower store whenever needed.

While analogies should not be confused with the real thing, we should not also forget their utility in suggesting possibilities and identifying profitable lines of investigation.

Association: the mind's glue

Do you now recall the urgent message, mentioned earlier, which invited some one to meet someone else in connection with a job? It will be useful now to take a minute to think about it and write it down as clearly as you can recall it. You can then compare it with the original. This small experiment on your own memory would give you information useful in answering a number of questions that are going to be raised in the following pages.

There is no denying that information elements such as what the telegraphic message told you to do, where, when and for what purpose, were in some sense associated together to form a complex idea in your memory. Given one of the elements, say, ' interview ', the mind is usually able to access the associated details. But theories which attempt to explain memory in terms of associations run into serious difficulties at an early stage. A classic example is the behaviourist attempts at explaining memory as nothing more than associations between stimuli and responses. Watson wrote: " By ' memory ' then, we mean nothing except the fact that when we meet a stimulus again after an absence, we do the old habitual thing (say the old words and show the old visceral-emotional-behaviour) that we learned to do when we were in the presence of that stimulus in the first place."

Did you recall the urgent message which invited some one to meet some one else in connection with getting a job? Now let us examine the results of the simple recall experiment you have performed on your memory. Compare the original telegraphic message with the question which made you recall it. Well, there are not many words common to the question and the message. So, if words are the stimuli Watson refers to, one cannot explain how this question evokes recall of the telegram. On the other hand, assume that associations occur between ideas, not words. One need not rule out associations of words, but grant that it is the association of ideas that is the more interesting type. The ideas of what to do, where, when and for what purpose could then be visualised to be in association. Making a theory of associations of such a type is itself a monumental task, one which has engaged the attention of philosophers and psychologists since the days of the Greeks.

Since such theories deal with associations between ideas, their supporters have to explain how the mind goes from words and sentences to ideas. Since ideas are not observable, one has to theorise about what they are and how they are obtained from what one hears and sees. Are there simple ideas and complex ones? Are complex ideas built up by associating simple ideas together, clearly indicating how each one is connected with another? In other words, are complex ideas structures built with simpler ideas? If that is so, does grammar play a role in determining the structure of association in a complex idea? Do the sentences we hear and read undergo a grammatical analysis to have their parts (such as verb phrases noun phrases, etc) identified to enable meaning to be assigned to them

[See the article by Prof. Narasimhan (pp. 28–33); language behaviour and long-term memory have to be studied together. It is practically impossible to talk about one without talking about the other.] Or is the process of 'decoding' the meaning of a sentence an integrated analysis in which all clues, grammatical or otherwise, are exploited equally? The influential linguistic theorist Noam Chomsky had suggested that grammatical analysis alone should assign deep structures to sentences which could then be subjected to a semantic interpretation to assign a meaning to the sentence.

The nature of meaning

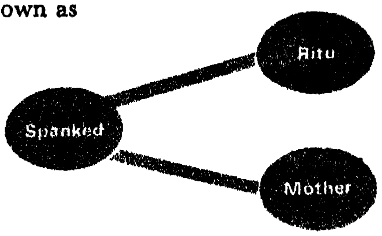
There is a general principle that all theories in this area have to honour. Postulated entities such as 'ideas' or 'meaning' should not be undefined or be loosely defined constructs. If that were to be the case, it will be useless to say that sentences are dealt with in terms of the ideas inherent in them. We would then have to construct another theory of what ideas are and how they are analysed, remembered, and so on.

An ideal solution would be to create a 'mechanistic' theory of ideas. For example, one could try to invent operations that can be carried out by a machine on the words of a given sentence which would result in a diagram or a set of 'equivalent sentences' embodying the ideas inherent in the given sentence. As long as 'the basic ideas' and the nature of allowed associations we postulate are mechanistic in the sense that they can be stored and be operated upon in a machine, we would be honest. Our theories could be subjected to a powerful test: can you get a machine to operate according to the principles of your theory, and simulate people's behaviour in answering questions based on the recall of information given earlier?

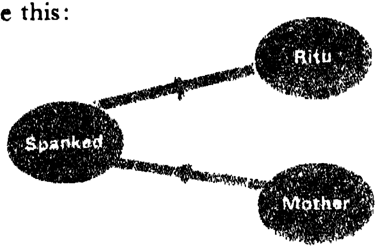
The standard practice is to program computers to handle information, analysing, storing and retrieving it as prescribed by a given theory; this gives valuable insight into the deficiencies of a given theory.

These attempts in simulation reached a notable degree of success with the experiments of Quillian whose work, reported in his PhD thesis and in later papers, have influenced associationist psychology considerably.

The value of simulation is that it forces one to work out a theory in detail. Consider, for instance, the suggestion that ideas can be thought of as nodes in a complex network which can be represented pictorially. Nodes which have an association between them are joined by a line. The sentence "Mother spanked Ritu" can be said to give rise to an idea shown as



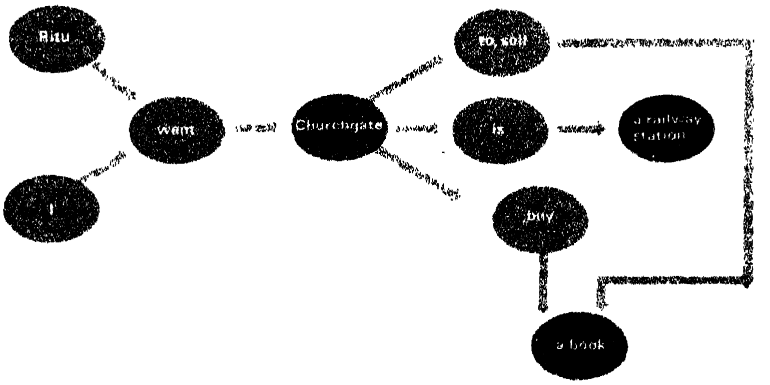
So, when someone asks what mother did, we can find the associative link from mother to "spanked" and answer it. This elementary proposal runs immediately into a problem. If the diagram is given to someone who interprets it mechanically, the question "who spanked who"? causes difficulties. Did mother spank Ritu or vice versa? So, clearly we need to add directional arrows to our diagram, like this:



Other questions arise very soon, as we go further in this direction. Consider the sentence:

"I went to Churchgate to buy a book."

Add to this the information that Churchgate is a railway station and that Ritu went to Churchgate to sell a book. Will not simple-minded addition to the network cause a structure like this?



Can a 'mechanical' search of this network find out "what you did"? Could it not say "I went to Churchgate to sell a book and Ritu went to Churchgate to buy a book"? Further, a mechanical search could say, "Churchgate bought a book", which is wrong. Even you may not have bought a book yourself, you only went to Churchgate to buy it. Further, was it the same book that Ritu went to sell that you went to buy?

Neo-associationism

Quillian's work in computer simulation of his associationist theory has stimulated work in this field by psychologists and computer scientists. Some agreement seems to be nearing in the matter of the role that grammar plays in the decoding of sentences and in the creation of structures that capture their meaning. Quillian had taken a daring step when he downgraded the role of grammatical analysis in comprehension in his model. A host of others have now followed in that direction, both in theory and in experimentation. The current trend places considerable importance on the use of a wealth of information in the comprehension process.

An example, rather popular with linguists, will illustrate the point being made here. Consider the sentences:

The pen is in the box (S1)

The box is in the pen (S2)

and consider their possible 'mechanical' analysis, for obtaining the information they carry. Further, assume that the mechanical analyser has dictionary information available to it in some form. This information

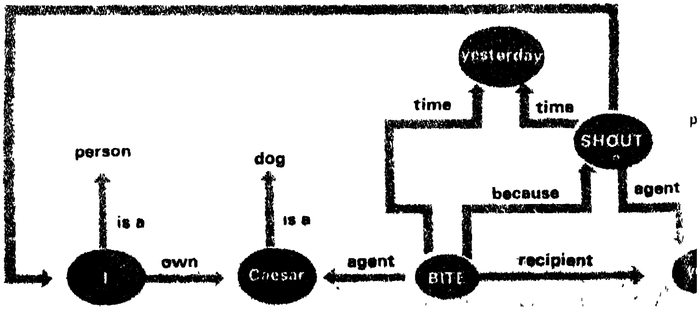


Fig. 10 Network of associations capturing the content of the sentence "My dog Caesar bit you yesterday because you shouted at me" (adapted from Lindsay & Norman)

gives definitions for the words " pen " and " box ":

Box: A container or case of wood, metal, etc.

Pen: 1. A writing instrument. 2. A small enclosure (as in baby's play pen).

Using a common notation to distinguish between the two senses of the word "pen", we can say that pen 1 is the writing instrument and pen 2 is the enclosure.

When you read the sentences S1 and S2, it becomes clear that the pen in S1 is really pen1 while in S2 it is pen2. How did you analyse S1 and S2 to obtain this distinction? One possibility is that you used the information that the pen is a rather small writing instrument and that play pens (and pig pens, for that matter) are rather large to fit into boxes. Another possibility is that such ' world information ' is not used in comprehension but some dictionary definition of words in terms of a set of well chosen categories will be sufficient to enable the assignment of interpretations to (S1) and (S2). The consensus now is clearly in favour of the use of ' world information '.

Structure of propositions: experimental verification

The Anderson and Bower model suggests that the *subject* is more closely associated to the *verb* and *object* than it is to the *location* or *time*. It similarly predicts that the *verb* is closer to the *subject* than it is to location or time.

Dosher asked subjects to study 14 sentences containing the constituents: AGENT(A) VERB(V) OBJECT(O) LOCATION(L) TIME(T). Then she presented them pairs of constituents such as *subject-location*, indicating the other constituents by dashes. For example, memory for a sentence read earlier can be tested by asking you to decide if the following partial sentence agrees with the one you have studied:

The ——— kicked the ——— in the desert on ———. Dosher calls this a *verb-location* probe.

The ' strength ' of the association (in this case between the *verb* and *location*) is estimated by a performance index d_t (basically an estimate of a signal to noise ratio, obtained by a complicated method). Dosher tested a variety of probes and the table below provides some information that her experiments have brought out. A high d_t in this table means a strong association.

Probe tested	Performance index d_t
Verb-Object	2·10
Subject-Object	2·08
Verb-Subject	1·75
Verb-Location	1·52
Location-Time	1·18
Verb-Time	1·08

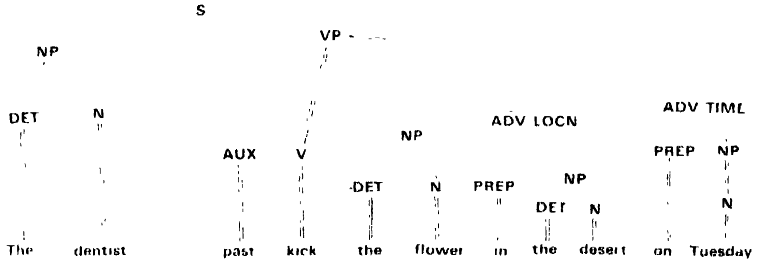


Fig 12 A grammatical structure for the sentence given in Fig. 11. Aux = auxiliary; Adv = adverbs, V = verb, Prep = Preposition; NP = Noun phrase; VP = Verb phrase; DET Determiner

The stuff that memories are made of

There are a number of associationist theories, worked out in some detail, that are free from faults of the kind mentioned earlier. The suggested reading list (p. 41) mentions several relevant references. Fig. 10 gives an idea of the type of associative structures such theories propose. An important effect of working out details has been that these theories are now making verifiable predictions.

Anderson and Bower, for instance, predict structures such as the one shown in Fig. 11. How different are these structures from the ones suggested by various types of grammars, for example, the one shown in Fig. 12? Anderson and Bower answered the question by predicting on the basis of their model how people will behave while recalling propositions after having read many of them. Read the following sentences and decide if the information they contain agrees with that of the proposition shown in the Figs 11 and 12 (without looking at the figures again). Dashes indicate parts of the proposition that are irrelevant to this test.

1. The dentist ————the —— on Wednesday.

2. ————kicked the————on Tuesday.

Anderson and Bower's predictions dealt with the question *what is more likely to be forgotten* (associations that are several links long) and *what is more likely to be remembered* (associations between nodes close to each other on the structure proposed). They obtained experimental results to compare with the predictions. Dosher used a more sophisticated technique, controlling the time available to the subject to make a decision, and investigating the percentage of correct yes/no decisions made. These experiments broadly support the type of structures shown in Fig. 11 in comparison to others such as the one shown in Fig. 12. The techniques involved are quite complicated and it is worth noting that the issue is not yet considered closed. The important point is that, proposals for associative structures are being taken seriously and are subjected to experimental verification.

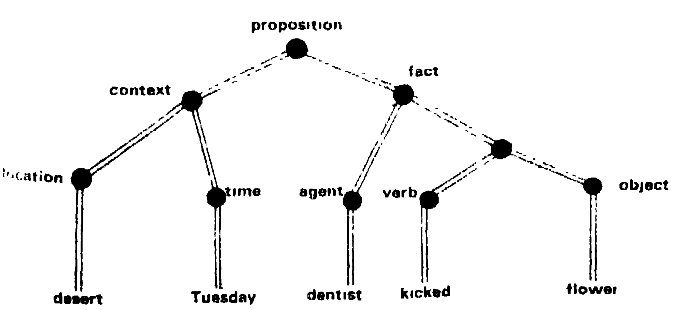


Fig. 11 Propositional structure for "The dentist kicked the flower in the desert on Tuesday." (From Dosher's paper)

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FOR FURTHER READING

The suggested reading list is divided into three sections: (1) Introductory, (2) Classical works, and (3) Others.

BIOLOGY

Introductory

1. Wooldridge, Dean E. (1963) *Machining of the Brain*. McGraw-Hill.
2. *Psychobiology: Readings from "Scientific American"*. W. H. Freeman & Co. (Has several interesting articles on the brain and memory.)

Classical works

3. Russel, W. R. (1959) *Brain, Memory, Learning*. Oxford Univ. Press.
4. Penfield, W. and Roberts, L. (1959) *Speech and Brain Mechanisms*. Princeton Univ. Press.

Other works

5. John, E. Roy (1967) *Mechanisms of Memory*. Academic Press.
6. Agranoff, B. W. "Memory and Protein Synthesis" in *Scientific American* (June 1967, Vol. 216, pp. 115–122).
7. Gazzaniga, M. S. (1970) *Bisected Brain*. New York Appleton-Century-Crafts.
8. Young, J. Z. (1966) *The Memory System of the Brain*. Univ. of Calif. Press.

PSYCHOLOGY & COMPUTER MODELS

Introductory

9. Hunter, I. M. L. *Memory*. Penguin Books.
10. Lindsay, P. H. and Norman, D. A. *Human Information Processing: An Introduction to Psychology*. Academic Press.

Classical works

11. Bartlett, F. C. *Remembering*. Camb. Univ. Press.
12. *The Neurophysiology of Lashley* (*Selected Papers of K. S. Lashley*) Ed. by Beach, F. A. *et al*. McGraw-Hill.
13. Lenneberg, E. H. *Biological Foundations of Language*. Wiley.
14. Hebb, D. O. *The Organisation of Behavior*. John Wiley (Paperback by Science Editions).
15. James, William. *The Principles of Psychology*. Holt (Reprinted by Dover).

Other works

16. Anderson, J. R. and Bower, G. H *Human Associative Memory*. John Wiley.
17. Dosher, B. A. "The Retrieval of Sentences from Memory: A Speed-accuracy Study", in *Cognitive Psychology*, Vol. 8 (1976).

Mnemonics: looking into memory aids

"How I wish I could recollect to places eight. . . ."

Some 25 years back, in school, the mathematics teacher had made us memorise those despairing nine words. My memory still retains them. The sentence, strangely, meant nothing, in the sense a grammatically constructed sentence is supposed to mean something. Those nine words stood for nine numbers, each represented by the number of letters in a word: 3 1 4 1 5 9 2 6 5; this is the value of π, if you put a decimal after 3, to eight decimal places. It was a trick, or shall we say, an ' aid ', to remembering. Similar aids are used by some of us to remember, say, a telephone number: "All the roads lead to Rome " — 33 54 24. Most of us do not use such aids — and these can range from simple codes to highly associative mnemonic systems — because we do not know how to go about organising items we *want* to remember. Perhaps this is what makes people fill in the coupons in those newspaper ads that claim to *own* the ' secret ' of improving memory — memory kits, memory courses, and so on. There is no secret formula of improving one's memory: it was known to the Greeks a couple of thousand years back. In 1891, William James wrote, perhaps, the last word on it: "*All improvement of memory consists in the improvement of one's habitual methods of recording facts* ". That's all there is to it, including those amazing skills displayed by stage performers calling themselves the " Memory Men ".

The prerequisite to improving one's memory is to condition oneself to paying increasing attention to relevant information. Attention has two components: (*i*) learning to better focus our attention and eliminate distracting and irrelevant sources of stimulation, and (*ii*) increasing our ability to detect what must be remembered and what needn't be.

What are the main types of material that require attention in order to be memorised? We could say, names, numbers, lists, everyday information and text-book material.

Recalling a face is easier than remembering a name. The face can be recognised as having been seen before, but a name has to be associated with something, say, a situation, or the face itself. So to remember a person's name, we have to learn to remember the individual features of a person's face, and of the person's name, and establish some connection between the two. The characteristics that should be remembered as relevant are not things like good looks, or dress or height, but *distinctive* features which set a person apart. (Remember, cartoonists make use of this attention-focusing ability to draw out a personality through just a few strokes of a sketch pen!) Attending to a name is more difficult and one can look for one of three clues: (*i*) Is it an unusual name?, (*ii*) Is it a common name? or (*iii*) Does the name, in some way, fit the face? A sure way of focusing attention to a name just heard is to repeat it, preferably in a sentence like, " It's a pleasure to meet you, Mr. Sahay "!

When it comes to commiting numbers to memory, attention can be focused on them by detecting *relationships within a particular number* you wish to remember. Take 753147. You notice the first three decrease by two the last three increase by three. Not all numbers have such obvious relationships, but if you are attentive, you can almost always find one. Try 342516. You can easily work out a relationship by pairing the numbers 34 25 16 each right-hand pair decreases from the previous pair by 9

Remembering a list is quite like remembering people's names, except that while names have to be attached to faces, lists have to be remembered as a series, and where required, in serial order. In learning pairs, we look for similarity between the two items In a series, we look for similarity among all the items. Say, you have to remember a shopping list containing potatoes, apples, grapes, peas, salt pepper, spinach, oranges and cinnamon. You can organise the list into three groups: vegetables, fruits, condiments, each group having three items Now it becomes easier, doesn't it?

Where order is important, attention must be focused not only on the individual items but also on items just before and after. We shall discuss some specialised aids to this in the section on ' mnemonics '.

Organisation

An interesting aspect of retrieval of information from memory is that the task depends to a great extent on the *way* the information was learnt. If one has to organise incoming information into their proper niche, it is necessary to use a pre-established system.

The oldest system of organisation is "chunking". It is fairly established that the maximum number of items one can learn by rote is seven; the number can be increased severalfold, if the items can be grouped into 'chunks'. To prove our point, we can try the experiment below.

Read the following numbers, then look away from the page and immediately try to recall them in order:

7, 4, 9, 5, 1, 6, 8, 3, 9

In all likelihood you will not be able to recall all the nine numbers, as they exceed the capacity of your short-term memory.

Now if you were to chunk the numbers into groups of three each, recall would be much easier. Try the following:

(749), (516), (839)

Recall here would be easier because you are handling *three* groups and not *nine* individual numbers.

However, chunking by itself will not help much if learning the list is not done actively. And active participation of the learner depends on his discovering some interesting feature and storing it in the memory. As for instance, scan the following list,

1, 9, 2, 8, 3, 7, 4, 6, 5

Did you notice anything interesting? The series begins with the lowest followed by the highest digit, then the next lowest followed by the next highest, and so on. Several hours or days later, you are sure to be able to recall the list!

Mnemonics

Besides chunking, there are two other techniques of storing information in long-term memory: (1) mediation, and (2) mnemonics. Mediation involves creating a link between items that you want to remember as belonging together. Mnemonics is a specialised predetermined system of placing items to be remembered in a rhyme or a story or an artificial schema.

Mnemonic systems have been known as *memoria technica* or artificial memory. Most of the present-day courses or kits of memory improvement use these, though few of us are aware that they were known to the ancient Greeks.

Let's start with 'mediation'. The most common form of mediation is to build a bridge — insert a word, say — between two items, which normally do not have a verbal relationship. Which is the capital of Poland? It's Warsaw. How would you remember that? World War II started with Germany's attack on Poland. So you remember Poland and WAR. Now the capital will always be easy to recall. This is only an example. You can find and establish such mediative links between almost any two (or more) items of information.

Mediation works rather well with numbers. The technique basically is to transpose each digit into a predetermined letter, and then combine the letters to form a word or words (with the vowels inserted in between). Let us take the word ROUND. The consonant R stands for 4 (the vowels *O* and *U* are of no importance), and N stands for 2 and D for 1. So, ROUND represents 421. It's easier to remember ROUND than 421 (say, the number of a hit-and-run car) because it has 'shape'. The code in this system varies from mnemonist to mnemonist, but we can adopt a fairly consistent one, as follows:

1 — t and d, t has a vertical stroke and d sounds like t.

2 — n and x; n has two vertical strokes and x has two diagonal strokes.

3 — m and w, m has three vertical strokes and w is m turned upside down.

4 — q and r; r is the last word of four, and the Latin word *quartus* — fourth.

5 — s and ss; s looks like 5.

6 — b and p; b looks like 6 and p sounds similar to b.

7 — f and v; f looks like 7 reflected in a mirror and v sounds like f.

8 — h, ch, c and j: h sounds like 8, and j follows the vowel i; c often combines with h.

9 g and k; g looks like 9 and k sounds like g.

0 — z and l; z for zero and l is left-over.

(We put Y amongst the vowels A-E-I-O-U-Y).

After you have learnt the code; you may have to use a little imagination while forming the word. Take 421. It can be written as r-n-t or r-x-d or q-n-t or q-x-d. Since both q and x are rarely used in fast word-construction, we choose r-n-t (or d): runt, rind, round. Round is better. It gives a shape.

"Shall we send them lesson No seven ? I've already sent three reminders to pay up the final instalment !"

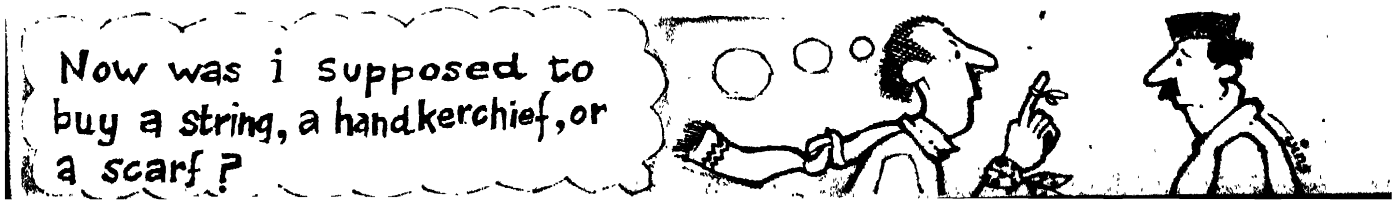
When there are many numbers, it's best to work with groups of three numbers while writing them into words. A four-digit number can be easily remembered by two words (a word for each pair). Take someone's birth date:

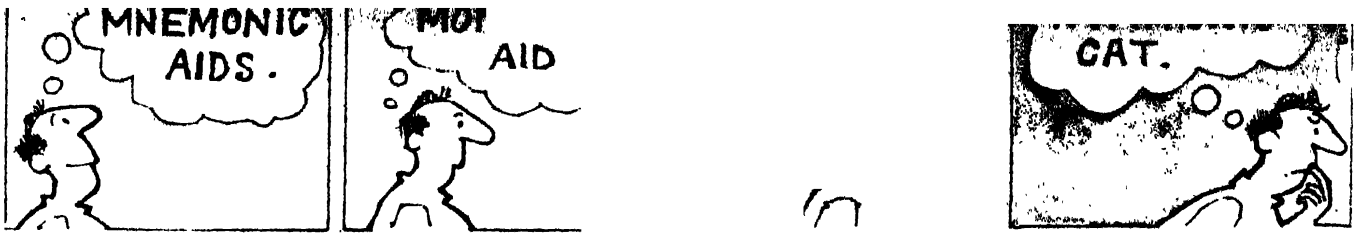
21. 4. 63 — NoTRe BuM (easy to remember since it reminds you of Notre Dame).

In mnemonic literature, one can find extensive tables of substitute words for all the figures between 1 and 1,000, and figures for every date in history — running into several pages. It would be advisable if you do not try to learn them by heart. It would be more rewarding if you devise your own code-words.

This type of digit-letter system is very old (the published reference dates back to 1684 when von Winckelmann of Germany published his 'most fertile secret') and has appeared in several forms, including the well-known (in UK) *Metrical Mnemonics* of Brayshaw, an English clergyman, which contained a collection of rhymes on over 2,000 dates and numerical facts drawn from history, geography, physics, astronomy, etc.

What the digit-letter system seeks to achieve is to fix an association according to a predetermined code. A similar but older method is the visual-symbol system, said to have been discovered by the Greek poet Simonides around 500 BC. It is also known as the 'locality' or 'house' system. Simonides stumbled upon the idea after he was able to identify the badly multilated bodies from a house collapse where a feast was going


Now was i supposed to buy a string, a handkerchief, or a scarf ?



on (he, too, had attended it but had left earlier) by recalling *where* each guest had been seated. In other words, if you wish to recall a series of names of people or objects, prepare the mental map of a room or a house and place the objects, each in a particular room or spot and, later on, as you recall the map, the object placed (mentally) in a location will automatically leap to your mind.

For an example, take the list: horse, cat, boat, tree, bear, dictionary, spectacles, hair brush, rose, bulb.

Now think of a house, preferably your own or one you know well. Imagine a HORSE tied to a post in the foyer. (What is a horse doing in a foyer? But, that's exactly it: the more bizarre the association, the more likely it is to stick in your mind!) From the foyer you move on to the living room. A CAT snuggles on the sofa. Next we move to the bathroom. There's flowing water and a tub. You wish you had a toy BOAT to play with in the tub. The bathroom leads to a passage, where a forest scene hangs from the wall. TREES. Trees remind you of a forest and a BEAR. You can't forget the bear. At the end of the passage is your child's room with a large teddy BEAR. The next room is a library. Books. DICTIONARY. You need reading glasses and you always leave one pair on the writing desk. SPECTACLES. Then you move on to the bedroom. The first thing you do after you wake up is brush your hair. HAIR BRUSH in a bedroom which opens on to a balcony: a ROSE plant in a tub. You water it and straight ahead everyday you look up to see a street lamp. It has a BULB. Have you made your map? Take some time as you place each object in the list to be memorised in a particular location. Then move on to the next. It's a sure bet that you won't forget the list and its order even after days.

The 'house' technique will work for a variety of memory tasks, like grocery lists, errands to run, points to make when writing an essay during an examination or when delivering a talk, or naming objects shown in a party game.

The 'house' technique is a mental peg (or map) technique. Another popular one is the "one is a bun" technique. It is described rather colourfully in the facing page. This has great advantages. First, the mnemonic is in rhyme, that is, each representational word rhymes or sounds very much like the number. Second, it can be used again and again, and third, it can be extended to include more than ten items by doubling up on the images.

It must be emphasised here that mnemonics work only through prolonged practice. It does not matter which method you use — 'house', 'one is a bun' or any other, as long as you are able to comfortably put the one you have chosen to use.

How effective are mnemonic systems? After all, as we have seen, they are designed to help the learning requirements of particular tasks like long, random sequences of words, numbers, lists, playing-cards. There is no doubt that, as far as these tasks are concerned, mnemonic aids do help — mainly because one can transpose information items into other items (images or predetermined schema), familiar to one and, therefore, easier to retain in long-term memory. But the question remains: how effective are they in improving memory as a whole? The answer, in all probability, would be, not enough, to be worthwhile. But, then, as I. M. L. Hunter points out in his *Memory*: "The mastery of some mnemonic system may lead some people to realise, for the first time, that they can control and modify their own mental activities. And this realisation may encourage them to undertake that self-critical examination with their own learning and remembering procedures which is such an important part of intellectual development".

Before we conclude, one point needs to be noted. Mnemonic systems can-

(Contd. on p. 59)

Memory courses: a few questions

As the accompanying article points out, there are many different mnemonic systems. Some of these are described in bulky volumes which are sometimes offered as mail order courses. Priced in hundreds of rupees, such courses are proclaimed to be very profitable by bold advertisements. Readers might be interested in some comments on such courses.

Will a memory course make me a better scholar?

No. The essence of mnemonic systems is that they help in making you remember uninteresting details. They usually make these more memorable by dressing them up in a colourful form. Advancement in studies, on the other hand, requires that the scholar should be truly interested in what he is studying. Uninteresting details can easily be kept track of by acquiring a couple of handbooks and by keeping a pocket notebook.

Schools sometimes place too much emphasis on numbers. "In which year did Vasco da Gama reach India?" A memory course could help one to gain marks by answering such questions by using a memory system. There is, however, a better alternative. Instead of using bizarre associations of the numbers to buns or biscuits, it would be much more useful to approach the subject by reading a genuinely interesting book on the subject. When the numbers *become meaningful* to you, bizarre associations are no longer needed.

Can I really improve my memory?

One should not expect miracles here. Would you expect to use your salary much better from what you learn in an economics book? Well-known psychologists have felt that one can improve one's memory by gaining some knowledge of the subject. Reading a good book on psychology can clear up some misunderstandings and give some hints on how one can alter one's mental habits. By providing a framework of ideas for analysis and discussion and by encouraging one's efforts in organising ones activity, such books could make a positive contribution.

Are there cheaper alternatives to memory courses?

It is very easy to find inexpensive books written by genuine scholars. Hunter's book mentioned in the reading list (No. 9, p. 42) is a good example. Such books are almost always a better bet than memory courses offered by purely commercial mail order houses. The books are available at a fraction of the cost of the courses. A 'course', after you have paid for it, can turn out to be nothing more than a book much inferior to Hunter's.

For those who wish to study memory aids in detail, we suggest a couple of inexpensive books:

1. ***Improving Your Memory* by Laird S. Cermak. 1976. McGraw-Hill Paperbacks.**
2. ***Conditioning Your Memory* by "The Memory Man" (Wolfgang Zielke). 1970. Cornerstone Library, New York.**

S. RAMANI

DEVELOP A SUPERMEMORY : AMAZE YOUR FRIENDS

This artificial technique of memorising (a mnemonic technique, in psychological parlance) is probably very old. It is described by several books on memory (including our reference 9, p. 41). We can practically guarantee that any reader who spends 15 minutes with it can memorise any list of 10 items (or less) such as this shopping list:

1. Oil
2. Sugar
3. Soap
4. Kerosene
5. Tomatoes
6. Razor blades
7. Syrup
8. Eggs
9. Biscuits
10. A magazine

The technique essentially involves hanging each one of these items on a *mental peg* — a numbered mental peg. If you are asked what is the fifth item in the list, just look at mental peg No. 5. What comes after eggs? Just search to see the number of the peg for eggs and then look up the next peg. Do you want to reel off the list in reverse order? Just look at the pegs in the reverse order.

All we have to tell you now is the trick of the mental pegs. Read this rhyme, three times. You will never forget it.

One is a bun,
Two is a shoe,
Three is a tree,
Four is a door,
Five is a hive,
Six is sticks,
Seven is heaven,
Eight is a gate,
Nine is a line,
Ten is a hen.

These 10 objects are neatly associated with numbers because of the similarity in their sound patterns. What object is mental peg number nine? A line, of course, a clothes line. Hanging objects of a given list on these pegs is easy. Let us try the shopping list. Read the following associations slowly, visualising each one in turn. You need not look back at any association. Once you have visualised it, it will stick in your mind.

1. Oil: One is a bun. Imagine a bun soaked in oil.

2. Sugar: Two is a shoe. Imagine a shoe filled with sugar cubes.

3. Soap: A cake of soap pierced by the sharp point of a tree branch.

4. Kerosene: A door soaked in kerosene; it may catch fire.

5. Tomatoes: There is a beehive on the tomato plant.

6. Razor blade: You are sharpening a stick. It reminds you of a blade.

7. Syrup: A cool drink on a hot and thirsty day — you are in heaven.

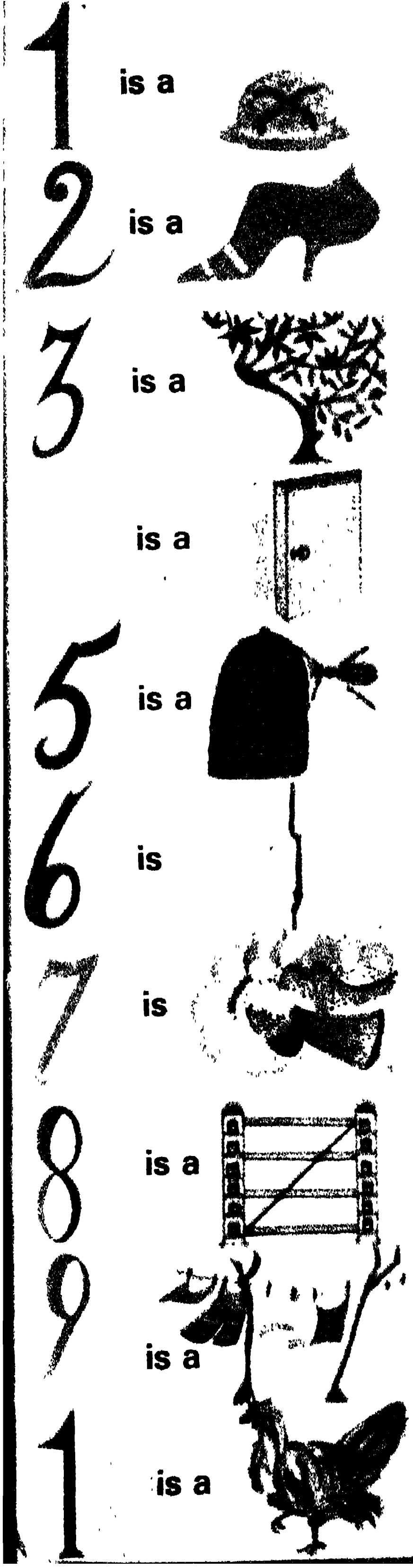
8. Eggs: Egg-shaped Humpty-Dumpty sitting on a wall next to a gate.

9. Biscuits: Hung from a clothes line, with laundry clips.

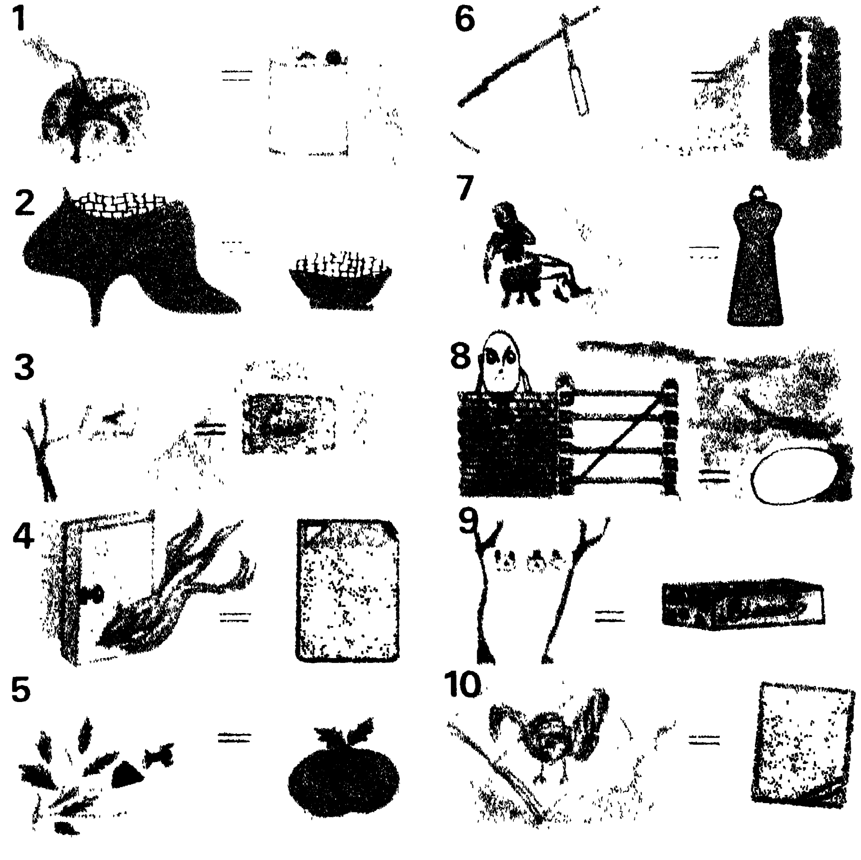
10. A magazine: You want to read it, but a hen is sitting on it possessively.

Finished? You can now hand over the SCIENCE TODAY to someone else and demonstrate to him your supermemory. What is the fifth item on the list? What comes before biscuits? Do we have bananas in the shopping list? What is the list in reverse?

S. R.



Sushma



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(Photostats of these can be seen at any office of Geoffrey Manners & Co. Ltd.)

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ROUND-UP OF RESEARCH

NUCLEAR PHYSICS

Spin Effects in Proton-proton Scattering

An experiment that may be a forerunner of others leading ultimately to the elucidation of the structure of the proton has been reported by a large team of physicists in the *Physical Review Letters* (**39,** 733, 19 September 1977). They have shown that proton spin has a large but curious effect on the way one proton bounces off another.

Spin is one of the fundamental properties of sub-atomic particles. It plays a small but important role in nuclear and atomic structure. The present understanding is that spin plays only a minor role in proton-proton elastic scattering. But, J. R. O'Fallon, L. G. Ratner and P. F. Schultz of Argonne National Laboratory, USA, K. Abe, R. C. Fernow, A. D. Krisch, T. A. Mulera, A. J. Salthouse, B. Sandler and K. M. Terwilliger of the University of Michigan, USA, D. G. Crabb of Oxford University, England, and P. H. Hansen of the Niels Bohr Institute in Copenhagen, Denmark, have from their experiments obtained results, surprisingly, quite contrary.

They bombarded a polarised proton target with a polarised proton beam (spins oriented in the same direction) produced in the Zero Gradient Synchrotron at the Argonne laboratory. They used a 70 per cent polarised proton beam of energy 11·75 billion electron-volts and a 65 per cent polarised proton target. They detected by means of a double-armed magnetic spectrometer events where the polarised-proton beam is elastically scattered from the polarised-proton target. From an analysis of measurements, the effects of spin were found most pronounced when the bouncing proton came off at a large angle to its original direction and at high energies.

The protons bounce rather well off each other when their spins are parallel. When the spins are anti-parallel, the protons appear to pass right through each other, as if they were transparent. Their data, in fact, indicate that the spin parallel interaction dominates the antiparallel interaction by a factor of two at a perpendicular momentum of 4·0 billion electron volts. They speculate from the combination of high energy and high scattering angle that something rather deep inside the target proton is responsible for the observed effects.

The results could be explained in terms of spinning charged clouds in protons or in terms of point-like constituent quarks with spin. On the quark-parton model, protons are indeed composed of three fractionally charged particles called quarks. Are quark spins responsible for the observed effects? What is the size of the quark? Only future experiments may be able to provide answers to such highly speculative questions.

MOLECULAR BIOLOGY

Synthesising an RNA Tumour Virus

RNA tumour viruses created history nearly a decade ago when it was shown that they can invade a cell and take over its machinery to reproduce themselves. They seemed to violate a fundamental dogma of molecular biology that DNA of which genes are composed is initially transcribed into a "messenger" RNA molecule which is then translated into the specified protein. It was later found that DNA was transcribed from the virus RNA and this DNA got itself integrated with the cell's genetic mechanism. The conversion from RNA to DNA is accomplished with the help of an enzyme, now properly termed "reverse transcriptase". (See Science Today, December 1970, p. 9.) The enzyme was discovered by Dr. Baltimore and Dr. Temin and they were awarded the Nobel Prize for 1975 in physiology or medicine for the discovery. (See Science Today, December 1975, p. 30.)

Ever since the discovery of reverse transcriptase, biologists have been attempting to simulate the process of copying of RNA into DNA in the test-tube so that it could be studied in some detail. But so far they had succeeded in synthesising only short segments of DNA from RNA templates. It was hence suspected that it may not be possible to make a complete DNA molecule without the intervention of cellular factors. Some recent studies, however, indicated that improved reaction conditions allow detergent-disrupted virus particles to synthesise DNA molecules 8,000 to 9,000 nucleotides long, the length of the viral RNA which serves as template.

Ellen Rothenberg, David Smotkin, David Baltimore and Robert A. Weinberg of the Department of Biology and Center for Cancer Research, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, now report in *Nature* (**269,** 122, 8 September 1977) that they have finally succeeded in perfecting a system in which full-length double-stranded DNA copies of purified mouse leukaemia virus RNA are synthesised. They used only the virus particle as the RNA template and the enzyme reverse transcriptase. What is more, the synthesised DNA molecules were shown to infect mice cells and produce complete infectious virus particles, demonstrating that all the information needed to specify the virus has been correctly copied from the RNA to the DNA. They found that neither RNA nor protein is required for infectivity, but it depends only on DNA. They conclude, "reverse transcription in purified virions may accurately reflect the mechanism of synthesis of the viral DNA in infected cells".

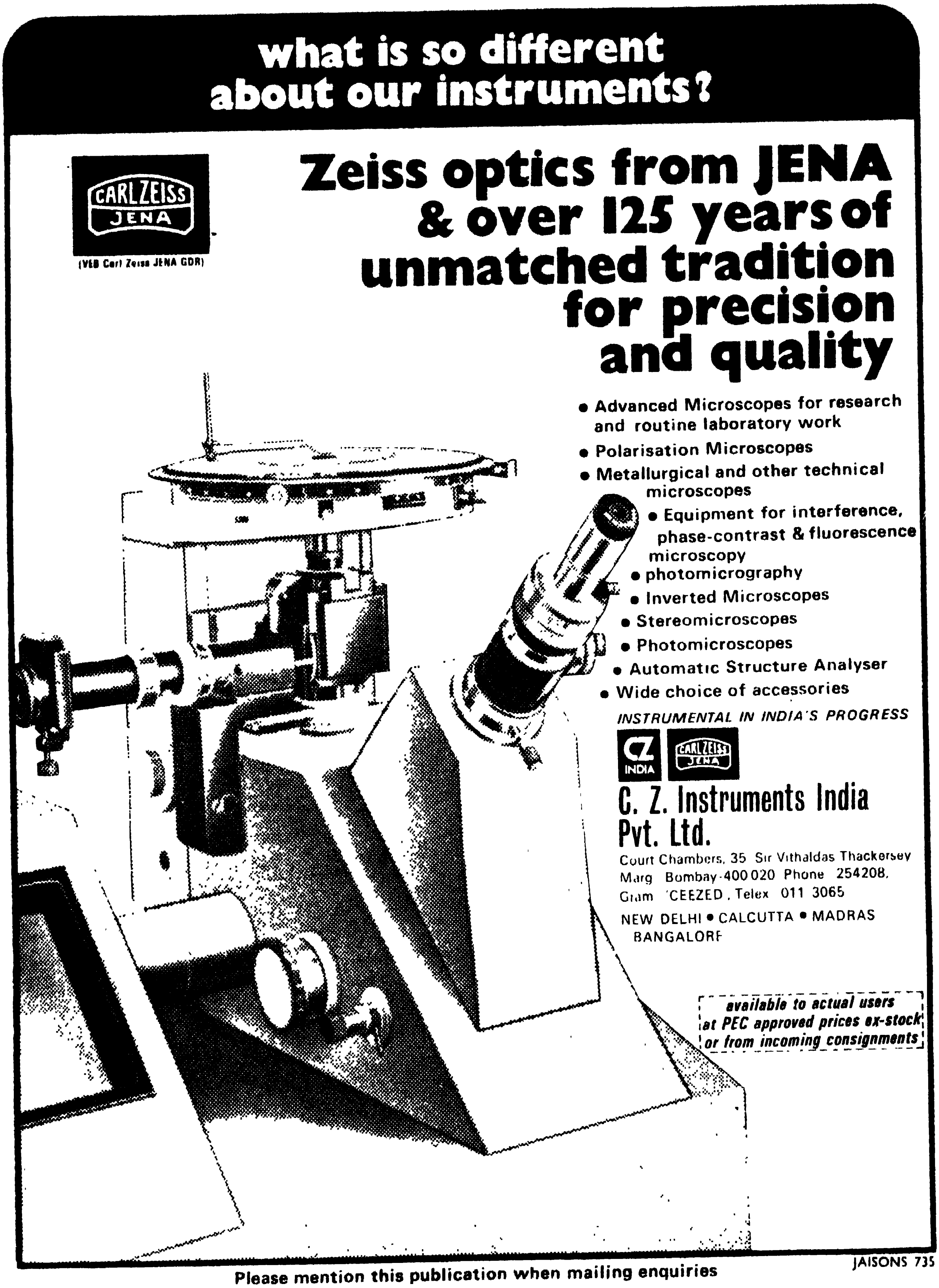
ASTROPHYSICS

Cellulose in the Cosmos

Further support to the suggestion that molecules of life may have originated in the vast space between stars has been provided by Prof. Fred Hoyle and Prof. N. C. Wickramasinghe of the Department of Applied Mathematics and Astronomy, University College, Cardiff, UK, in an article in *Nature* (**268,** 610, 18 August 1977). They have presented evidence, though indirect, for the presence of cellulose, the chief component of the cell walls of plants, in interstellar matter.

More than three dozen molecules have so far been discovered in interstellar space and the number is steadily mounting. One property of the abundant molecules of formaldehyde (H_2CO) is that they can link together to form a complex chain (polysaccharide) by a process known as polymerisation. The resultant molecules can form stable ring structures such as starch and cellulose that are capable of resisting the degradation by ultraviolet radiation from stars. This radiation prevents most molecules such as H_2, HO and CO from existing for long periods in space.

While the point whether cellulose really forms in space in this way is disputable, astronomers have good enough evidence that the interstellar space consists of vast clouds of dust and gas. The British physicists have been studying, during the past few years, the absorption of infra-red radiation by dust grains. The results



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of the studies carried out by means of balloons and rockets have been particularly interesting in that the dust appeared to absorb infra-red radiation strongly at two wavebands, centered at 3 microns and 10 microns. These were identified as due to water-ice and magnesium silicate, respectively. It was thus natural to attribute the infra-red properties of interstellar dust to a mixture of water-ice particles and magnesium silicate grains. But it was later found that the detailed correspondence of a silicate-ice model to the observed infra-red spectra of a wide range of galactic sources is not good. The discrepancy was intriguing since silicate and ice are simple materials.

Cellulose, being of economic importance to the cotton industry, has been studied extensively at infra-red wavelengths in the laboratory. Hoyle and Wickramasinghe have now compared the properties of interstellar dust at infra-red wavelengths with the properties of cellulose-like materials at these wavelengths They found that the infra-red absorption of cellulose-like materials occurs at exactly the same wavelengths (3 microns and 10 microns) as that of interstellar dust It was also possible to explain in some detail the infra-red spectra of a number of sources on the assumption that cellulose is indeed present in the interstellar matter They could readily relate astronomical data in the 2-4 micron, 8-13 micron and 15-30 micron wave bands.

They state that " the identification of this highly complex macromolecule could have a profound bearing on interstellar chemicals including the evolution of prebiotic molecules ".

MEDICINE

Can Chronic Bronchitis Prevent Pneumoconiosis?

Pneumoconiosis is an occupational hazard of coal miners and is caused by the inhalation of coal dust. Coal miners are also subject to chronic bronchitis, the reasons, besides the dust exposure, being tobacco smoking, air pollution and respiratory illness during childhood. The clinical role of bronchitis is to mask the ventilatory function tests in simple pneumoconiosis. In fact, some epidemiological studies had suggested that bronchitis might indeed have a protective action against the development of pneumoconiosis. D. C. F. Muir, J. Burns, M. Jacobsen and W. H. Walton of the Institute of Occupational Medicine, Edinburgh, Scotland, have in a report to the *British Medical Journal* (**2,** 424, 13 August 1977) tested the above hypothesis, using data from a major long-term epidemiological survey in the British coal mining industry.

The study included 4,883 men who were radiologically examined initially for the presence of simple pneumoconiosis. The presence or absence of persistent sputum in them was also ascertained by a questionnaire. The men were again examined ten years later for pneumoconiosis. The dust inhaled by individuals during the ten year period was calculated from dust sampling results and detailed records of attendance at work. The amount of exposure to dust by the individuals before the commencement of the survey was estimated from information on earlier industrial histories. The amount of dust inhaled (gh/m^3) was obtained by multiplying measured airborne concentrations (g/m^3) by the number of hours worked.

The results of the initial survey indicated that, as expected, there was a greater proportion of men with persistent sputum among those with pneumoconiosis. Confining only to the 4,356 men with no pneumoconiosis in the initial survey, it was observed that 11 per cent of those with persistent sputum present developed pneumoconiosis ten years later, as compared to 7·3 per cent in those with no persistent sputum, despite the fact that the former group had slightly lower dust exposures on the average. Their results were thus in contradiction to the hypothesis that sputum production. protects against pneumoconiosis. In fact, they present evidence that the probability of developing pneumoconiosis depends on the cumulative exposure to respirable dust and was little affected by the presence or absence of symptoms of sputum.

The Scottish doctors conclude that their results are compatible with a simple model in which dust in coal mines may cause pneumoconiosis, bronchitis or both. According to them, it is unlikely that airflow obstruction, irrespective of mucus hypersecretion, has a protective action.

BIOCHEMISTRY

A Desert Shrub Grows Rubber

A team of chemists from the Fruit and Vegetable Chemistry Laboratory, Western Region, Agriculture Research Service, Pasadena, California, USA, and the Jet Propulsion Laboratory, Pasadena, have demonstrated in an article in *Science* (**197,** 1076, 9 September 1977) the induction of natural rubber in the desert shrub guayule (*Parthenium argentatum*) by treatment with the chemical 2-(3, 4-dichlorophenoxy)-triethylamine. (See also SCIENCE TODAY, June 1977, p. 9.) Their results suggest that the production of rubber can be increased by the use of chemical agents on guayule and other rubber-forming plants.

Guayule is native to the Chihuahuan Desert of north and Central Mexico and the adjacent Big Bend region of Texas. The plant can be grown in arid and semi-arid lands, and during the Second World War the plant was extensively investigated as a source of natural rubber in the United States. The programme, however, was terminated when synthetic rubber was developed.

H. Yokoyama, E. P. Hayman, W. J. Hsu, S. M. Poling and A. J. Bauman have reported the results of tests on entire seedlings (four months old) grown in the greenhouse and of subsequent experiments on field-grown guayule plants (eight months old). The seedlings were treated with 5,000 ppm of 2-(3, 4-dichlorophenoxy)-triethylamine, 5,000 ppm of 2-diethylaminoethanol and a wetting agent. Controls were treated only with 2-diethylaminoethanol and the wetting agent. The former chemical appeared to influence the magnitude of the plant response to 2-(3, 4-dichlorophenoxy)-triethylamine. The plants were harvested three weeks after treatment and were in a state of vigorous vegetative growth when the rubber content was analysed. They found a two- to six-fold increase in the amount of polyisoprenoid rubber accumulated in the stems and roots of the treated plants. The rubber was present as a latex in parenchymatous cells.

The American chemists state that in accordance with the results of other experimenters on guayule plants, the magnitude of response in field-grown plants may be greater when treated during periods of water stress or dormant growth than during periods of vigorous vegetative growths. Also, larger yields may be expected from plants more than a year old. The resins of this plant may also be as valuable as rubber since they contain terpenes—important chemical intermediates. However, the effect of triethylamine on the composition of the resin fraction still remains to be explored.

K. A. NEELAKANTAN

JAL D. PARDIVALA

The credit to "view with the mind's eye the discus style shot putt technique" definitely goes to the Russian Alexander Baryshnikov who was the first successful exponent way back in 1972. With this technique (at Montreal, 1976) he claimed the bronze medal with a throw of 21 metres (68 ft 11 in), though in the qualifying rounds he had established a new Olympic record of 21·32 metres (69 ft 11·5 in). Just prior to the Montreal Games, on 10 July 1976 at Paris, he established a new world record of 22·00 metres (72 ft 2·25 in).

However, the longest throw in the world has been achieved by the American Brian Oldfield, who had putt the shot to an amazing distance of 22·86 metres (75 ft) in a professional track meet held on 10 May 1975 at Al Paso, Arizona, USA. Oldfield had achieved this mark through the "rotational technique" — said to be an improvement on the Obrien style. Parry Obrien's idea was to bring in more power by going further and further back in the ring and facing more and more backwards. According to Oldfield, the "rotational technique", which is a pivot at the back of the circle, gives an extra 3 feet (1 metre) advantage to the thrower's motion.

Here is a photographic analysis of his throw:

(1) Picture one is a stance at the back of the circle, the typical discus turn with the body weight initially on the right foot. A slight rotation of the upper body to the right is visible.

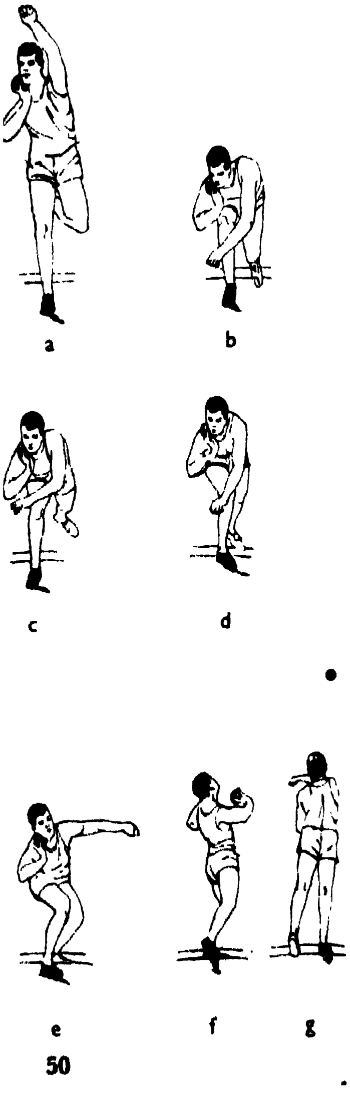
(2) The beginning of the 'discus style spin', pivoting on the left foot around the toes. This movement, according to a technical expert, enables the thrower to extend the range of the "momentum-gaining phase", that is, to accelerate the shot as soon as the right foot takes off.

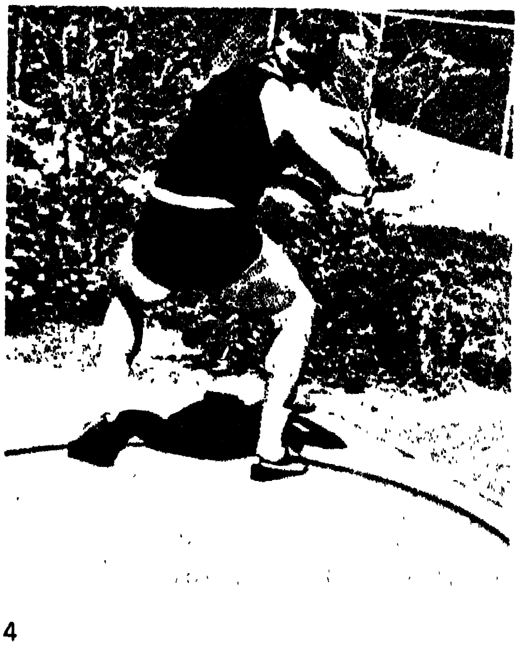
(3) Half-way through the turn, the drive from the back of the circle towards the centre begins. This gives "the important linear drive through the circle".

(4) The right leg lands near the centre of the circle to begin the greatest implementation of another turn which according to Oldfield is 360°. Landing on the right toe, Oldfield is trying to come all the way round to a forward position.

(5) Here he is half-way through the final turn. Two points to note are, (*i*) the upper body is not only over the hips but also over the right knee, and (*ii*) this position is almost similar

(Below) The conventional shot-putt technique. (Right) Photo series of Brian Oldfield's 'rotational' throw





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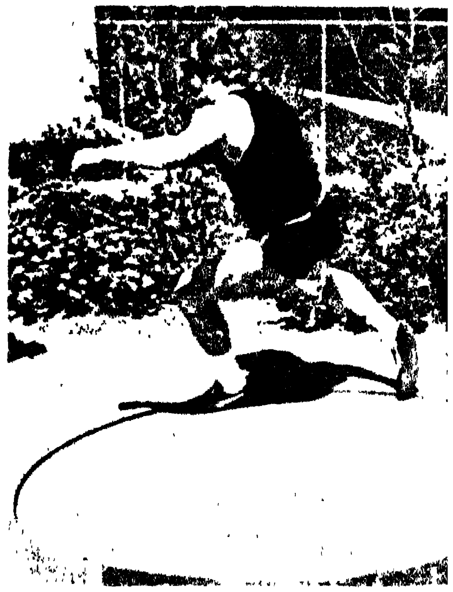

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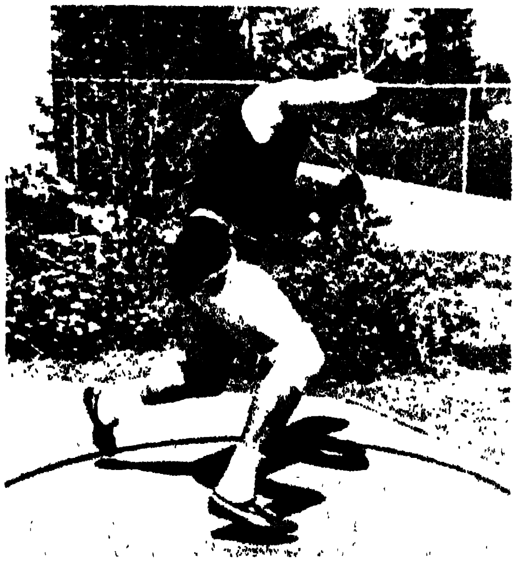

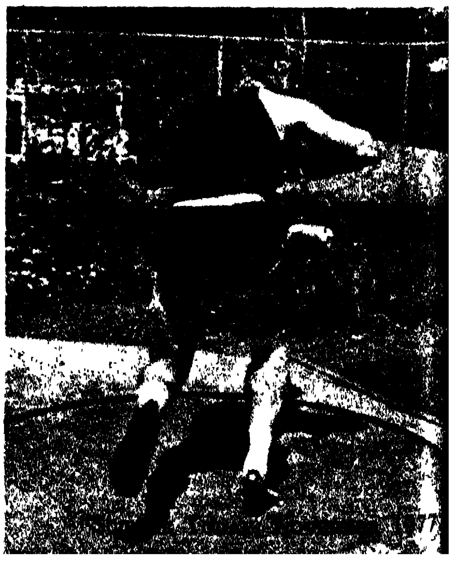

to the Obrien style position in the act of gliding. (See Figs. 3 and 5, " The Science Of Shot Putt ", SCIENCE TODAY, February 1977, pp. 47–49.) In the picture, the left foot of Oldfield is about to come down. Oldfield believes that in the rotational technique, the putter not only has 3 feet (1 m) extra advantage in the initial stages of the whole movement, but THE HIPS SLIDE INTO POSITION MORE EASILY.

(6) This stance is equivalent to the Obrien style, except that the left foot has gone very much in the bucket particularly in this picture which is not correct. The body mass is still on the right leg, though he is on the point of starting the rotation of the trunk. The right elbow is exactly behind the shot and is almost at an angle of 45°. The little finger and the thumb are opposite each other. The left arm is locked-in to prevent further unwanted rotation.

It is believed that when the " rotational technique " is faultless, good results are achieved. But, as one coach sums up, " faults such as loss of balance and inaccurate foot placement caused by insufficient leg strength are, however, heavily penalised by very poor results, and also, of course, uncontrolled shots while taking the turns can be dangerous to onlookers and others."

And talking about discus... Al Oerter is back!

Remember Al Oerter? Four times Olympic champion, the first man to exceed 200 ft (60·8m), the " nonpareil of discus throwing "? Our article on discus throwing (SCIENCE TODAY, May 1977) had begun with a quote from Melvin Watman's *Encyclopaedia of Athletics:* " He seemed destined for greatness when he set an American schoolboys' discus (3 lb 9 oz = 1·6 kg) record of 184 ft 2 in (56m) in 1954; but few could have anticipated he would develop so speedily that only two years later (at the age of 18) he won an Olympic gold medal. His repeat victory in 1960 was less surprising. Oerter's third triumph in 1964 ranks amongst the greatest competitive efforts in athletic history for he was in acute pain.

" His achievement in winning an unprecedented *fourth* Olympic title in 1968 made him the most outstanding competitor in the annals of athletics. . . . It was not until 1962 that he laid claim to the world record. He made history by throwing 200 ft 5 in (61·10m), lost the record 17 days later to Vladmir Trusenyov of the USSR, and recaptured it with 204 ft 10 in (62·3m) — after a further lapse of 27 days. He improved it to 205 ft 5 in (62·5m) in 1963 and 206 ft 6 in (62·8m) in 1964 for further world records. . . . It was a relief to those with 1972 Olympic aspirations that Oerter decided not to try for the fifth victory."

The 'relief' wouldn't last. Al Oerter is now hoping to make the 1980 Olympic Games at Moscow.

Al Oerter left the athletic arena in 1969 to spend more time with his two young daughters. Seven years would pass. In 1976, Oerter was taking part in a filming session with Bud Greenspan during the making of a segment for *The Olympiad* television series. After the filming, Oerter realised he simply wanted to throw the discus again. After a couple of false starts, he sat down and mapped out a time-schedule. " I don't think I've been out of condition since I was eight years old," he said. " This year I'd like to throw 200 ft (60·96m), next year 215 ft (61·54m), the next 225 ft (68·58m), and 235 ft (71·64m) in 1980. If I can reach these goals, it will put me in a class that — given the right conditions — anything can happen. . . ."

In April this year, Oerter had surpassed his 1977 target by throwing 205 ft 1 in (62·52m), his best mark since winning at Mexico City in 1968. The mark is, of course, far behind Mac Wilkins's world record throw of 232 ft 6 in (70·86m) established last year. Al Oerter will have to work hard indeed.

How does he plan to go about it? " I will keep working on strength, then I'll start throwing the 35 lb (15·75 kg) weight. It's complementary to the discus because you have to be fast in the ring to throw the weight. Not only is strength difficult to regain, but I'll have to increase mine by 25 to 30 per cent. I won't throw in any more big meets this year, just some development meets at St. John's where I can pay my quarter and throw. That way I can throw or lift the night before and not worry about technique. I'll start throwing with the fine discus throwers next year. I suppose I could throw 210 ft this year, but then I'd probably throw only 211 ft next year. It's a building thing."

And talking about 1980, Al Oerter is realistic: " It's going to be tough to get up there with Mac (Wilkins)."

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A tube that tells on tipplers

A simple device for screening drivers of motor vehicles for alcohol consumption may prove a boon to traffic police constables. It has been developed by the Central Scientific Instruments Organisation (CSIO), Chandigarh.

Many road accidents are due to the drunkenness of drivers whose efficiency and judgment is impaired by the consumption of alcohol. The concentration of alcohol in the blood is almost universally accepted as a reliable indicator of intoxication, but it is not always possible or convenient to conduct blood tests. Fortunately, the relationship between the level of alcohol in the breath and that in the blood has been found to be reasonably constant for practical purposes. Therefore, in many countries of the world, breath alcohol analysis tubes have been adopted for the determination of the blood alcohol concentration for several years. In the United States, people can be convicted on the basis of the breath analysis alone. In most countries, a blood alcohol level of 80 mg per 100 ml has been accepted as the legal level for convicting purposes.

The device developed at the CSIO is in the form of a small disposable glass tube. It detects alcohol in the breath and provides immediate information whether or not the driver suspected of having consumed alcohol should be sent for blood examination. The gadget can be used for simple roadside screening tests. If the test is positive, the person could be taken to the police station and asked to provide a specimen of his blood or urine. If the alcohol level in the blood exceeds 80 mg per 100 ml of blood, he may be convicted.

The gadget consists of an indication tube containing a yellow-coloured substance and is accompanied by a breathing bag and a mouth-piece. The person to be tested for drunkenness is asked to blow through the mouth-piece till the bag is fully inflated. It takes 10 to 20 seconds to completely inflate the bag. The blood alcohol concentration is indicated by the yellow substance turning green almost instantaneously. In case the blood alcohol level exceeds 0·08 per cent or more, the discoloration reaches the red band marked on the tube. The extent of change of colour of the tube is proportional to the concentration of alcohol in the blood.

Extensive tests with this device have been carried out at the Post-graduate Institute of Medical Education & Research (PGI), Chandigarh, by analysing the blood alcohol level in the human subjects after administering a measured quantity of alcohol to them. The experimental results excellently correlated with the level indicated by the tube. A few sample tubes were given to the Chandigarh and Haryana Police Departments for field trials. These trials have been found satisfactory and a few persons have been convicted on the basis of this device. Various state governments in the country have expressed interest in this gadget for mass scale applications.

The design of the gadget has been perfected and the know-how released to a public sector undertaking.

The operation of the gadget is very simple. The traffic police constables would experience no difficulty in carrying out the tests on the roadside.

The tube is disposable and can be used only for one test.

. . maybe a peg too many?

New technique for sulphur dioxide removal

Sulphur dioxide in the atmosphere in excess amounts is bad to human health. And the increased use of coal following the high price of oil can cause increased SO_2 emission in the atmosphere. Though lime is now used to scrub flue gases industrially, the process does not remove all the SO_2. Several other processes to remove SO_2 from stack gases have been proposed, but none has attained a commercial status.

A new process which uses iron sulphide for SO_2 removal has recently been reported (*Chemical & Engineering News*, **55** (22) 24, 1977). Iron sulphide is abundant in pyrite mine tailings, and disposing of it is a problem. It can be used to recover sulphur from stack gases. The process is based on a gas-solid reaction between sulphur dioxide and a sulphide of iron. The solid is mixed with the stack gases as an atomised slurry. The reaction product is an unstable compound which precipitates out. A final step reconstitutes the original iron sulphide, leaving pure marketable sulphur.

The process is 90 to 98 per cent effective in removing sulphur dioxide. The process is efficient between 40 and 4,000 ppm of SO_2, while most other processes need at least 400 to 500 ppm. The process also consumes less energy. The flyash left over is not of objectionable composition and the residual carbon in the flyash is a useful reductant in the regeneration step.

The capital and operating costs are estimated to be one-half to two-thirds of other regenerable systems such as carbon reduction. The process could be wet or dry; the system could be regenerative or non-regenerative, that is, a small company could build only half the system and send the precipitate to a central system for recycling or just discard it as land-fill. The precipitate will be much easier to handle than the limestone sludge in the conventional method using lime, where the sludge is in a slurry form.

Pilot plant trials of the process have shown good promise. An integrated facility is being set up at a Westinghouse plant in Pittsburgh, USA. If the process really shows all the advantages expected, it will help several countries utilise their huge deposits of high-sulphur coal.

V. C. MALSHE

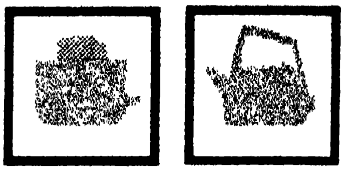
NEXT MONTH

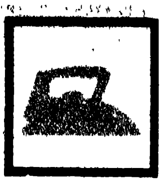
A special section on

STATISTICS & THE COMMON MAN

and a revealing article on teaching science in village schools

THE HOSHANGABAD VIGYAN—A UNIQUE EXPERIMENT





HOW GOOD ARE OUR ELECTRICAL APPLIANCES?

P. J. JOGLEKAR
S. T. PATIL

Food mixers and grinders, washing machines, hair dryers, shavers, etc are all motor-type appliances. The heart of all motor-type appliances is the fractional horse power electric motor (1 horse power = 746 watts). A typical washing machine uses a motor of 1/8 to 1/3 horse power. Typical food mixers use motors which consume about 300 to 400 watts. Hair dryer motors consume about 100 watts.

There are various types of fractional horse power motors. The motors used in mixers are called universal motors (see box). They can operate on both AC and DC. They are series motors capable of operating at very high speeds of the order of 14,000 to 18,000 rpm (revolutions per minute). On the other hand, washing machines use induction motors which work at a speed of about 1,400 rpm. Motors used in hair dryers are of the universal type, whereas in shavers synchronous motors are used which work at a constant speed.

Motors operating at high speeds, as in mixers, must rotate smoothly. For this, there has to be a complete circular symmetry in its rotor. This is called balancing. If this balancing is not proper, the motion during one complete revolution is not smooth but jerky. This causes unequal stress on the bearings which support the rotor. Obviously, there will be uneven wear and tear which will cause further imbalance and the machine will get damaged in a short time. To avoid this, it is necessary to balance the rotor very accurately. Electronic dynamic balancing machines are very efficient. However, most of the manufacturers in India do not use these machines. This is why their motors are not as good as they should be.

The manufacture of stator winding also needs attention. Vacuum impregnation technique must be used to reduce losses and increase insulation. In our survey, we found that even a progressive and enlightened manufacturer was using only ordinary impregnation.

It is not that these techniques are very new or unknown but it appears

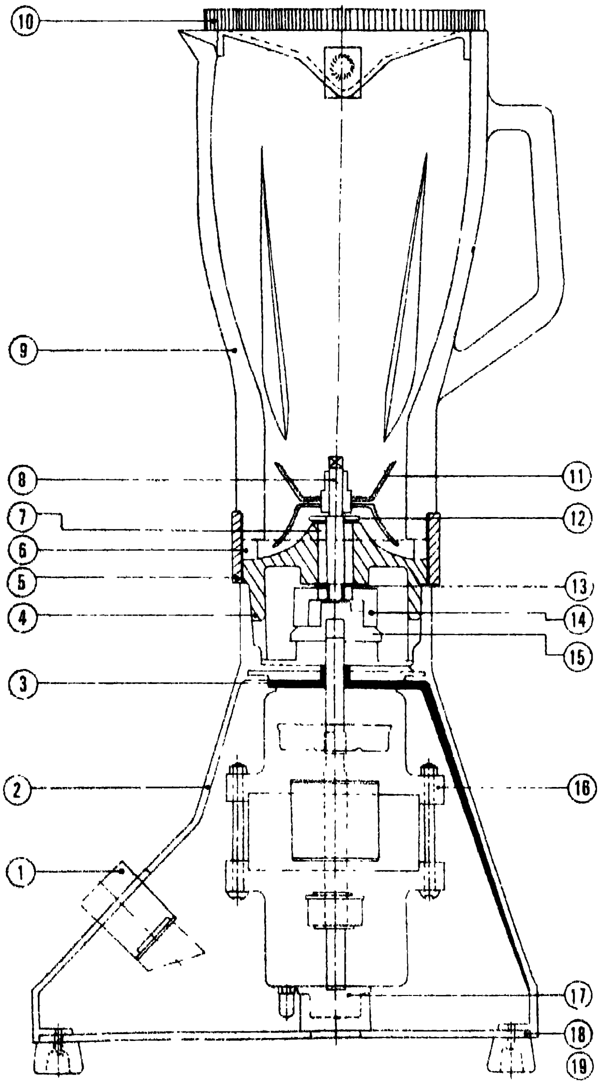


Fig. 1 (left) The constructional details of a food mixer/grinder. The numbered parts are: (1) switch assembly (2) body (3) bypass (4) cup (5) skirting (6) ring (7) bush (8) spindle (9) jar (10) cover (11) liquidiser blade (12) cap (13) washer (14) coupling driver (15) coupling driver (16) motor assembly (17) motor support (18) base plate (19) mixer support and (20) aluminium jar

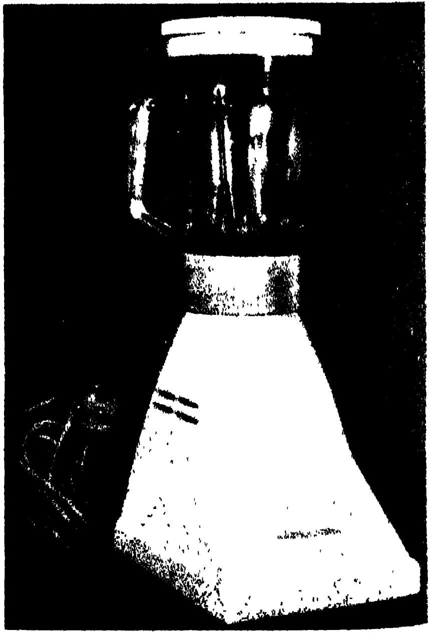
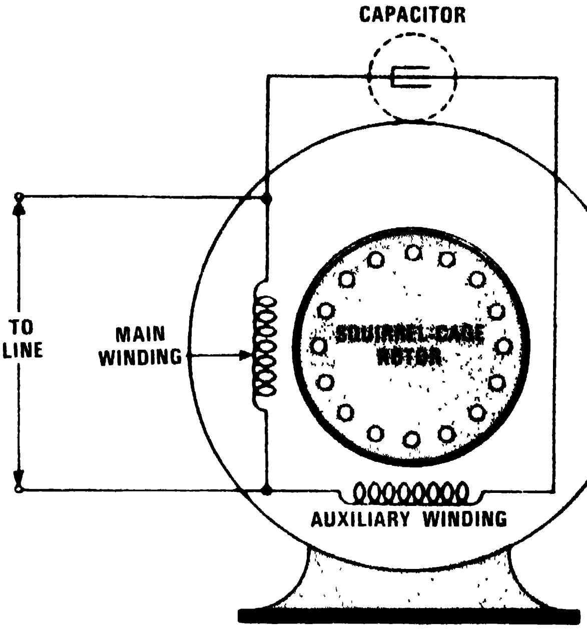


Fig. 2 (right) The food mixer/grinder

FRACTIONAL HORSE POWER MOTORS



Permanent-capacitor split-phase motor

An electric motor converts electrical energy into mechanical motion. This is based on the well-known principle that a current-carrying conductor placed in a magnetic field experiences a force in a direction perpendicular to both the directions of the electric current and the magnetic field.

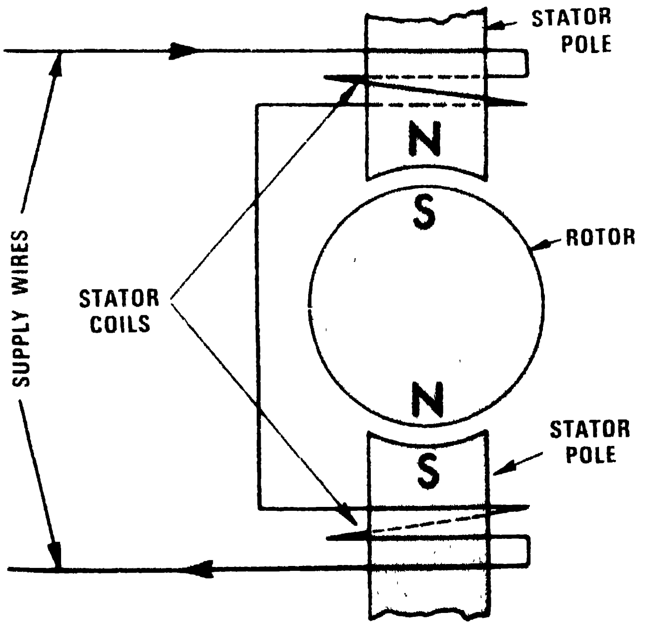
DC series motors and 3-phase AC induction motors are the commonly employed types in large motors. But there are a host of industrial and domestic uses of electricity which require only a small amount of power. For these applications, fractional horse power motors are used which work on single phase supply.

Universal motors are similar to DC series motors and they can work on DC as well as AC supply. They are used where speeds greater than 3,000 rpm (revolutions per minute) are required. The speed of these motors is quite high on no load and decreases with increase in load. (DC series motors cannot be operated on no load at all as they can attain very high speeds damaging the motor. Universal motors usually do not reach such damaging speeds.) The speed of a universal motor can be adjusted by connecting a resistance of a proper value in series with the motor. The speed changes with a change in load and also with changes in supply voltage and frequency. These characteristics are undesirable in some applications and in such cases AC single phase motors are used.

AC motors are of two types -- synchronous and induction. The speed of a synchronous motor depends only on the number of magnetic poles and the supply frequency $\left(\text{rpm} = \frac{120 \times \text{frequency}}{\text{Number of poles}}\right)$. A two-pole motor (one north pole and one south pole) will have a synchronous speed of 3,000 rpm for a 50-cycle supply. A synchronous motor is used in applications which require constant speed such as wall clocks and tape-recorders. Synchronous motors are not usually used in applications which need a fairly large amount of power and never where the speed must be controlled like in fans.

Induction motors work at speeds slightly less than synchronous speeds. In 3-phase motors, a rotating magnetic field is produced due to currents in the stator windings. This rotating magnetic field pulls the rotor. In single-phase motors, there is no rotating magnetic field. The simple unit is shown in the figure on the left. It would merely stand and hum without turning because the magnetic force is in the vertical direction and there is no lateral force to cause rotation. If, however, the rotor is turned rapidly by mechanical effort, a voltage is induced in the moving rotor conductors as they sweep across the magnetic field. The resultant current interacts with the magnetic field due to the stator, and the rotation is maintained. Single-phase induction motors are made self-starting by providing some additional features. A second stator winding called the starting winding is provided in split-phase motors. The capacitor motors, on the other hand, have an auxiliary winding connected in series with a capacitor across the supply (see figure).

P.J.J.
S.T.P.



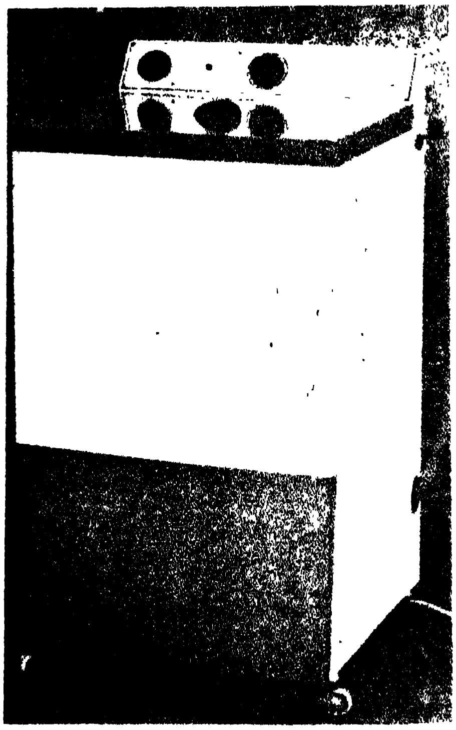
A simple single-phase motor

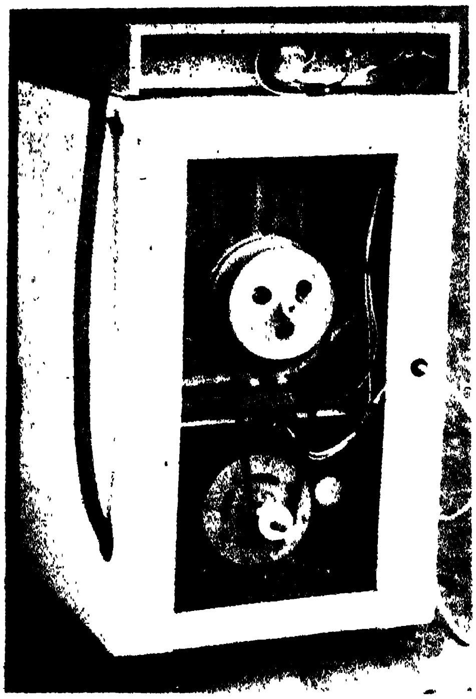
that the manufacturers are reluctant to use them for reasons of economy. A new motor will function satisfactorily, but when it starts giving trouble after some time it is difficult for the customer to prove that the manufacture was defective. The dealer can always blame the customer for misuse and negligence. In motor-type appliances, compliance with endurance test requirements of the Indian Standards Institution can, therefore, protect the interests of the customer (see box on p. 57).

The constructional details of a typical grinder mixer are shown in Fig. 1. The grinder portion is used for pulverising or powdering dry foodstuffs like groundnuts, cereals, coffee seeds, etc. A separate lid is provided for the grinder. When the liquidiser is to be used, it is fitted on to the grinder portion and the liquidiser blades get coupled to the motor. In another model, the container is common for both the operations, but the blades are changed. The containers are made of either stainless steel or glass or thermosetting plastic. It is necessary that the material used for the container bowl is neutral to food, acids and salts, does not deteriorate with age and is able to withstand temperatures up to 100°C without change in its physical, mechanical and chemical structures and properties. The cutters and other exposed parts of the machine in contact with food must be made of material which prevents fouling of foodstuffs and resists corrosion and rusting. The mechanical coupling between the motor and the cutter spindle poses some problems (see box on p. 57). To allow for variations in positioning different parts in assembly by the user, small axial and radial displacement must be tolerated by the machine. At the same time, accurate guides have to be provided to ensure proper mounting.

Fig. 3. (below) The washing machine

Fig. 4. (bottom) The motor (bottom) and the impeller or the agitator (top) in a washing machine. At the top of the machine is the control panel





Some precautions are necessary on the part of the user. These are usually given in the instruction sheets supplied with the appliance. The more important points are that the motor should not be started without load, that is, without any foodstuff in the mixer (otherwise the motor attains rather high speeds); there should not be excessive quantity of foodstuffs, either. In the latter case, the motor fails to rotate and draws excessive current. Besides, certain types of foodstuffs like turmeric (*haldi*) and betelnut (*supari*) may be too hard for the cutting blades of the grinders. Fibrous foods like coconut and ginger also pose difficulty in some mixers.

The mixers imported about 15 years ago were generally of the light duty type suitable for European food. They could operate for periods of not more than one minute or so at a stretch. The Indian mixers now available are of the heavy duty type which can operate continuously for 30 minutes.

Washing machines

In India, washing machines have not found a good market. The machines manufactured in our country are of the non-automatic type. This means that successive operations in the complete process of washing require one or more interventions from the operator. The basic unit consists of a washing tub. The clothes are immersed in the tub in a washing solution which is agitated by blades rotated by an electric motor. The main parts of such a washing machine are: (*i*) water container made of stainless steel or aluminium, (*ii*) impeller driven by an electric motor, (*iii*) outer body of mild steel sheets, (*iv*) an ON-OFF switch and indicating pilot lamp, (*v*) wringer consisting of two rubber rollers and a handle, (*vi*) timer (optional), (*vii*) internal water heater (optional), and (*viii*) drain pipe.

If the motor causes the agitator rotate in one direction only, a regul motion is established in a short tin Better results are obviously obtain with irregular motion. One meth to obtain this is to reverse the dir tion of the agitator blade rotation frequent intervals.

The wringer squeezes out the wat from the clothes by pressing t clothes between two rollers whi are operated either electrically manually. A centrifugal extracti unit, which contains a basket operat by a motor, turns the basket expel moisture centrifugally from t clothes. Another desirable facility to heat the washing solution to required temperature. Since differe fabrics require different temperatur a temperature-controller is desirab Addition of all these facilities mak the machine complex.

An important part in a washi machine is the rubber gasket at t impeller shaft. This prevents wat from leaking out at this point. inefficient gasket will let the wat seep through and reach the main pa of the outer body and the elect motor. This will affect the mot insulation and the motor can g burnt. The main parts would also subjected to rust and get corrod faster.

With a washing machine of t above type, the following temperatu and time duration for the vario types of fabrics are recommended.

Fabrics	Temperature in °C	Time in minutes
Cotton/cotton blended		
White	75 (very hot)	
Fast colours	55 (hot)	
Moderate fast colours	40 (warm)	
Wool/wool blended		
White	40 (warm)	
Fast colours	35 (warm)	
Moderate fast colours	30 (lukewarm)	1
Synthetic and mix fabrics		
White	50 (hot)	2
Fast colours	40 (warm)	2
Silk	50 (hot)	1

(*Note:* Increase the time by one minut while washing in cold water.)

It is advantageous to pass t clothes through a wringer before ri ing; it helps to recover soap soluti When the machine is not in u

STANDARD TESTS

It is well known that an equipment or an appliance which has moving or rotating parts gives more trouble than an equipment which has no moving parts. Motor-operated appliances are, therefore, more prone to trouble. The wear and tear of the motor parts will eventually lead to defects, not obvious at the time of purchase. A customer, therefore, takes a chance when he buys a product which has not established a reputation for quality and which has not been certified by a competent authority after thorough testing. This makes it desirable to carry out the tests specified in the relevant standards laid down by the Indian Standards Institution.

The endurance test is the most important in assessing the long-term performance of the appliance under test. For motor-operated appliances, the test prescribes continuous operation for 48 hours at a supply voltage slightly in excess of the prescribed maximum rated voltage and for another 48 hours at a supply voltage slightly less than the minimum voltage. At the end of the test, the insulation should not be damaged and contacts and connections should not work loose as a result of heating, vibrations, etc. There should be no deterioration which can impair safety in normal use

The routine tests are intended for 100 per cent inspection (see " How to ensure quality ", October 1977, p. 49). They include: (*i*) visual examination, (*ii*) protection against electric shock, (*iii*) high voltage, and (*iv*) insulation resistance tests. All these tests are to be carried out by the manufacturer as prescribed in the standard on general and safety requirements (IS 302 1973). Earthing connection test is also specified as a routine test (except in the case of shavers). This test measures the resistance between the earth terminal of the appliance and each of the accessible metal parts in turn. The resistance should not exceed 0·1 ohm. This would protect the user of the appliance if the earthing in the house is properly done Otherwise the hazard will still be there (SCIENCE TODAY, September 1977). It is, therefore, essential to have the earthing tested, particularly before going in for a washing machine. There have been fatal accidents with washing machines due to carelessness in these matters. If the earth terminal in the socket is not connected to a good earth, it can have some high voltage due to the leakage current in the entire installation in the building, including the particular machine. Therefore, it offers no protection at all. Any metallic part of the washing machine can thus have a high voltage on it. Wet hands will make good electrical contact with the metallic surface of the machine. And wet feet and the water spilled around will make good contact with actual earth. Thus the whole voltage will appear across the body resulting in a severe shock.

In addition, the following tests are prescribed as routine tests for the appliances described in this article. For mixers, an operational test with recipes is prescribed. This includes: (*a*) grinding coffee, (*b*) preparation of the idli mix, and (*c*) whisking egg whites. The quantity and quality of foodstuff in each case is specified. In the first two cases, the end product is passed through appropriate sieves to decide the quality. In the case of eggs, the bowl is inverted for five seconds and the material which would be in the form of a stiff froth must remain in the bowl. If the end product passes the tests prescribed, the result is considered satisfactory.

In the case of washing machines, a running test is prescribed in which the machine is put on without load and the various controls are checked for proper operation.

The acceptance tests which are meant for inspecting on a sampling basis include a few more tests in addition to the routine tests. The following tests are prescribed for all the appliances: (*i*) moisture resistance, (*ii*) leakage current, (*iii*) input, and (*iv*) temperature rise. The moisture resistance test is to find out whether the appliance is proof against humid conditions which may occur in normal use. The appliance is kept in a humidity chamber which contains air at approximately 27° C and more than 95 per cent humidity for 48 hours. After the treatment, the appliance should not show any damage. Besides these tests, performance test for washing machines and temperature withstand test for mixers are included in acceptance tests.

The performance test for washing machines meticulously gives details about the quantity of clothes to be used, the composition of soiling and how it is to be done. A mathematical formula is given for the evaluation of soil removal but the august body has not specified what the final values should be. The standard published in 1971 noted that these were " under consideration " (but the amendment issued four years later was still silent on this point). The subsequent clause prescribes in solemn words: " The fabric which emanates after the treatment shall be as clean as it was prior to its being moistened and dirty. This shall be judged visually ". The subjective judgement at the end of the elaborate test makes it of doubtful utility.

In the temperature rise test for mixers, boiling water is poured into the bowl rapidly to fill it to capacity. The bowl is emptied and brought back to room temperature. After repeating this five times, the bowl should not show any sign of cracks.

The type tests cover the full range of performance requirements and check the basic design. Naturally, they include various tests which are taken from the standard on general and safety requirements. Two tests deserve special mention. They are the spillage test and the starting test. The spillage test is prescribed for appliances subject to spillage of liquid in normal use to ensure that it does not affect their electrical insulation. For this test, a specified quantity of water is deliberately poured slowly in the bowl already filled completely with water. The insulation is checked after this spillage.

The starting test for motor appliances prescribes starting the appliance 10 times under the most unfavourable load conditions in normal use and at a voltage equal to 0·85 time the rated voltage. In all cases, the appliance should function safely.

The mixer and the washing machine are costly appliances. The tests described above will assure the customer about the quality of the appliance. Hence compliance with ISI standards should be enforced more rapidly in the case of these appliances. Such a step will be in the interest of both the consumer and the manufacturer.

P.J.J.
S.T.P.

precautions should be taken to dry all accessible parts, particularly the area around the rubber rim at the top of the machine. The only maintenance is to lubricate the impeller shaft and the motor at times with a proper lubricating oil and to adjust the ' V ' belt, when it is loose.

In western countries, fully automatic washing machines are manufactured with built-in water heaters and spin-dryers. For thorough cleaning, the impeller rotation is reversed after eight to ten rotations. The dirty soap water is removed after some time and fresh water is allowed in the container. Finally, the clothes are put in a spin-dryer from which they come out practically dry and ready to iron. All these operations are fully automatic. Once the temperature and time durations are adjusted and a starting push-button is pressed, the machine stops automatically after the washing and drying process is completed.

Hair dryers

Hair dryers use a small fan to blow air. If one needs hot air, a heater element is switched on by a separate switch. The air gets heated as it flows over the heater element (Figs. 5 and 6). A universal motor is used to drive the fan; it consumes about 100 watts. The heating element consumes about 200 watts. The hair dryer is a hand-operated appliance and may be held by the user in various positions. The motor, therefore, should be mechanically stable. As mentioned earlier, motor-driven appliances need to be tested over a period of time to check their reliability. Since the manufacturers are reluctant to subject their appliances to rigorous tests by an independent authority, customers have doubts about the long-term reliability of the appliances. It is, therefore, both in the interest of manufacturers as well as customers if the manufacturers carry out all the prescribed tests satisfactorily.

Shavers of indigenous make are not available in the market. It is understood that a shaver made indigenously was introduced in the market some time ago. But it was found to be unsatisfactory and had to be withdrawn from the market after refunding money to some customers.

Two of the features, "For Young Readers" and "Let's Get to Know Our Trees" have been held back this month owing to lack of space.

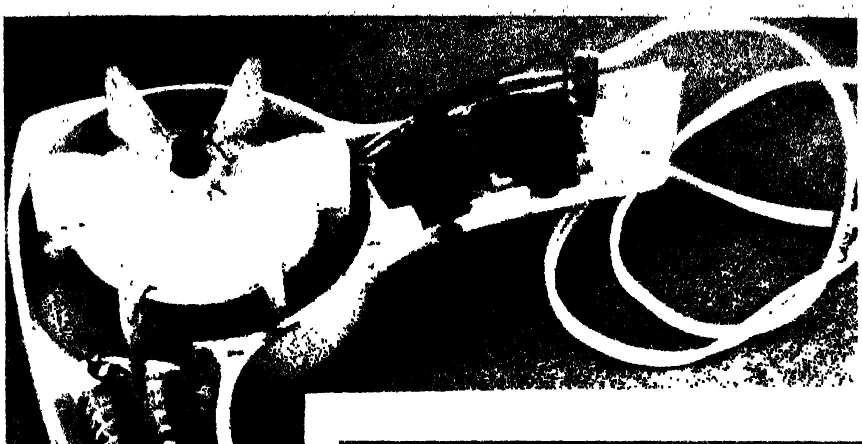


Fig. 5 (above) The main parts of a hair dryer, the fan and the heating element. The heater is switched on by a separate switch. The air gets heated as it passes over the heating element

Fig. 6 (right) Hair dryer

AWARDS APPOINTMENTS

ICMR Awards

The Indian Council of Medical Research has selected 16 scientists for its 1977 awards in biomedical research.

Dr. R. Viswanathan, emeritus scientist at the V. P. Chest Institute, Delhi, and Dr. R. N. Chowdhuri, former Director of the School of Tropical Medicine, Calcutta, jointly receive the Dr. Kamala Monon award in internal medicine — Dr. Viswanathan for the study of chest diseases, and Dr. Chaudhuri for tropical diseases.

Dr. S. S. Jolly, Professor of Medicine, Patiala Medical College, has won the Basanti Devi Amir Chand prize for his work in endemic fluorosis. Dr. P. K. Devi, Professor of Obstetrics and Gynaecology, Post-graduate Institute of Medical Education and Research, Chandigarh, has been awarded the Dr. P. N. Raju prize for studies in maternal health.

Other award-winners are Dr. M. I. D. Sharma, emeritus scientist, National Institute of Communicable Diseases, Delhi — Dr. Y. S. Narayana Rao oration award for work in the control of communicable diseases, particularly the eradication of smallpox. Dr. Kamala Krishnaswamy, Assistant Director, National Institute of Nutrition (NIN), Hyderabad — Dr. V. N. Patwardhan prize for work in nutrition. Dr. K. K. Datey, Director of the Department of Cardiology, Medical Research Centre, Bombay — Kalawati Jagmohan Das memorial award for work in cardiovascular diseases. Dr. S. J. Guleria, Professor of Medicine, All-India Institute of Medical Sciences (AIIMS), New Delhi — M. N. Sen oration award for research in respiratory diseases; Dr S. Padmavati, former Director of the Maulana Azad Medical College, New Delhi — Kshanika oration award for work in cardiovascular diseases. Dr. B D. Barua, Professor of Pathology and Bacteriology, Assam Medical College — Sandoz award for studies in the epidemiology of oral cancer. Dr. P. K. Ray, former Director of the Chittaranjan National Cancer search Centre, Calcutta — Raja Ravi S Singh award in the immunology of can

Four young scientists (below 40) h been awarded the Shakuntala Amir Ch prizes They are Dr S N A R Lecturer in Medicine in the Maulana A Medical College, New Delhi, Dr Sati Singh Hanjan, Department of Biochemi AIIMS, New Delhi, Dr. S K Bharg Assistant Professor of Paediatrics in Safdarjung Hospital, New Delhi. Dr Ramesh Bhat, NIN, Hyderabad.

BRAIN TEASERS

LOST IN TRANSIT : Mr. Shambhu wrote and published an interesting book. He despatched some copies to a wholesaler in another town. All were lost in transit. Then he sent as many bundles of copies as the number of copies he had sent earlier, each bundle containing the same number of copies as in the first consignment. These were also lost He then sent some copies through as many persons as there were copies in the second consignment, each person being given as many copies as the number of pers Now, the copies lost in the third cons ment were equal in number to the sec consignment copies. The remainder delivered to the wholesaler, twelve reta approached whom and agreed to tak these copies, provided each of them go same number of copies. Did the reta get their copies ?

V. A. SHE

(Solution next month)

Solution to last month's Brain Teaser

Carom with a difference:

Since each strike fetches either of them one point, there were 17 strikes in all, of which the first player made nine and the second, eight. Let the first one have X unsuccessful strikes; hence, the second will have had 7 — X unsuccessful strikes. Further, the first player had 9 — X successful strikes so that he got (7 — X) + (9 — X) ie, 16 — 2X points.

Now 16 — 2X = 9 or 8
Since X is an integer,
16 — 2X = 8, and X = 4

Hence, the first striker got eigh points, and the second won the game

BOOKS

The weather weapon —some facts, some fiction?

THE WEATHER WEAPON by N. Seshagiri, National Book Trust of India, New Delhi, 1977, pp. 190, Rs. 10

Dr. N. Seshagiri has written a very readable book His capacity to present scientific concepts in popular and picturesque language is rare among Indian scientists. His capabilities as a scientist and his flair for popular scientific writing could have been used to present a more balanced picture of the subject.

In the preface, Dr Seshagiri says that the book was written solely for discussing scientific issues, though he expects the reader to suffer " a mild chill down the spine " by the time he comes to p. 127. The book should be judged by the first criterion.

The book doesn't give a definite presentation of the present state of weather modification Unfortunately, the author believes that the opinion of the world community of meteorologists that weather modification is still largely at the research stage is a ' consciously hoisted canard ' to divert attention from developments of significant strategic importance. The World Meteorological Organisation, in a policy statement, had cautioned 'that weather modification ' operations should be undertaken ...... on the understanding that the desired end results may not always be achieved". The table at the end of Chapter III on " Types of environmental modification and their assessment as weapons " taken from the document submitted by Canada to the Geneva Disarmament Conference is scientifically realistic in taking into account foreseeable developments. But Dr. Seshagiri's method of presentation is to describe some apparently successful experiment and to extrapolate the results up to a level of fantasy to create a chill down the spine, which effect he has himself admitted.

The book correctly mentions some sub-systems of the monsoon circulation of South Asia, to which monsoon rainfall is related. Some of these features are over adjoining oceans and neighbouring countries. The author calls them soft spots; by tampering with these, the Indian monsoon can be dried out. In spite of the study of the monsoon for a hundred years, meteorologists are unable to explain the wide fluctuations in rainfall as cause-and-effect relationships with precedent conditions. Yet Dr. Seshagiri is bold enough to state that " parameters governing the structure of the monsoon are precisely quantifiable and predictable " to plan an attack on the monsoon. As a consequence of the drought weapon, he even pictures that a " government may crumble or political chaos may ensue " !

In this and other cases of weather weapons, Dr. Seshagiri has failed to appreciate the fundamental problem encountered in assessing the success of weather modification experiments. Given an initial state of the atmosphere, the future state is predictable not uniquely but in a probabilistic manner. These probabilistic limits of predictability of weather phenomena and the order of weather modification possible by various techniques so overlap that success can be defined only at various levels of statistical significance, even after trials over a long period. At present, a military commander, having sent his aircraft on a cloud-seeding mission, has to be content with the belief that any floods caused thereby are probably not due to natural forces!

" The seeding of hurricanes has been followed by reduced maximum wind velocities. Confirmation is required from further experiments which should include an increased number of measurements in pertinent regions of the storm." No more is claimed in the 1975 statement of the World Meteorological Organisation on hurricane modification. The book, on the other hand, informs the readers that hurricanes of 1961, 1963, 1969 and 1971 have been steered by seeding. Neither the article of R. C. Gentry, the then Director of National Hurricane Research Laboratory in the book *Weather and Climate Modification* (Hess 1973), nor the " Editorial Overview " (1976) of the American Meteorological Society on " Weather Modification ", mentions any steering of hurricanes by seeding. Dr. Seshagiri's conjecture on p. 62 " that if a number of cyclones are suppressed in the same area and often, the energy conservation factors may cause the creation of super giant cyclones " is pure fiction. He also mentions on p. 102 " a study, by the author, of simulating on the CDC-3600 computer of TIFR a typical operation for controlling the direction of a hurricane so as to hit a specified port or naval installation." This secret work would indeed be a valuable addition to the arsenal of any country!

Interest in weather weapons has been stimulated by the use of seeding to cause flash floods in the Vietnam war. The techniques should have been similar to dynamic seeding of cumuli and cumulonimbus mergers practised by the Joanne Simpson group. Limitations of this method have to be recognised. The considerable US mastery in air in the Vietnam war made it easy to seed clouds in border areas and in the interior of enemy territory. During the monsoon sway, clouds suitable for dynamic seeding might be common, but tampering would not be easy and effective except with air superiority. This seems to be about all there is about weather weapons to reckon with to date. Research, no doubt, is in progress at an increasing tempo by the two Super Powers to exploit other possibilities, but there has been no breakthrough like the silver iodide seeding agent which opened up the vista of regulating the formation of ice crystals.

The author creates a scare of weather modification experiments and operations. Such a scare may beset national programmes with several problems.

Y. P. RAO

[Dr. Rao is Director-General of Observatories, India Meteorological Department, New Delhi.]

MNEMONICS

(Contd from p 44)

not be very effective in learning textbook material. The student's learning does not merely involve verbatim recall. The material that needs to be stored in his mind must be ' understood ' rather than ' memorised '. Even where factual details need to be memorised, the requirement is not so much a faithful reproduction in an isolated performance as in the context of a generalised problem-solving situation. To quote Hunter again: " Practice in memorising does not of itself improve ability to learn; even ability to learn the kind of material on which practice was expended. But practice can be effective if it is taken as an opportunity to explore, discover, and modify the activeness of learning . . . it can often lead to the development of more effective learning techniques ".

PRADIP PAUL

Entropy and the source of biological order

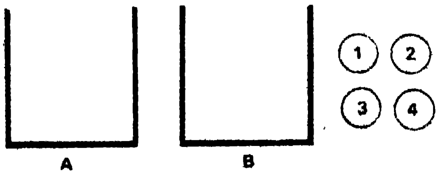
Let us begin with the question: " What is order? " Everybody is familiar with this as a qualitative notion. A rush hour crowd milling around on a railway platform seems ' disordered ' in contrast to a group of school children neatly arrayed for a P.T. display. A newly-built skyscraper is an ordered conglomeration of concrete blocks and steel rods; if it collapses, what remains seems less orderly to the intelligent layman. In fact, any society itself is an organised complex of production, circulation and distribution, to say the least. And corresponding to its degree of development, there is a definite correlation and interconnection between its various parts. Each part—be it a person, a production unit or a component of a machine — is placed in definite and precise relation to the remaining system.

Now the maintenance and reproduction of these social systems of organisation of factories, households, economies, etc require the constant efforts of intelligent agents — human beings (however shortsighted and anarchic these efforts may be when evaluated in a historical perspective), and hence it is not difficult to see where the dictum arises that " *any* process of organisation requires the intervention of a conscious, intelligent agent ". But is this true?

Before we examine the validity of the above notion, let us sharpen our tools by *quantifying* the concepts of order and disorder, at least in simple cases. What we can do is to quantify the closely-related concepts of " information " and " lack of information ". A measure of the latter is known as ' entropy '.

Consider two containers labelled A and B, and four balls, numbered 1, 2, 3 and 4 (Fig. 1). Let us say we have *complete information* about this system when we have specified exactly in which container each ball is situated. And let us agree to call each such ' exact ' specification a ' detailed state ' of the system.

Fig. 1



Consider now the three following specifications of the system (Fig. 2).

(*a*) Container A has four balls in it.

(*b*) One of the containers has four balls in it.

(*c*) There are two balls in each container.

Fig. 2a

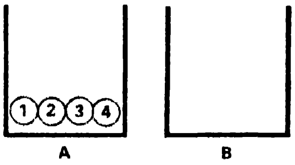


Fig. 2b

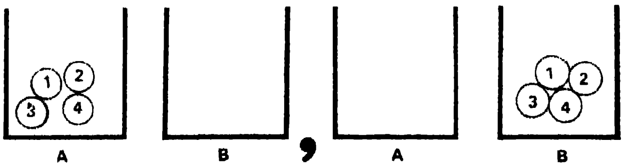
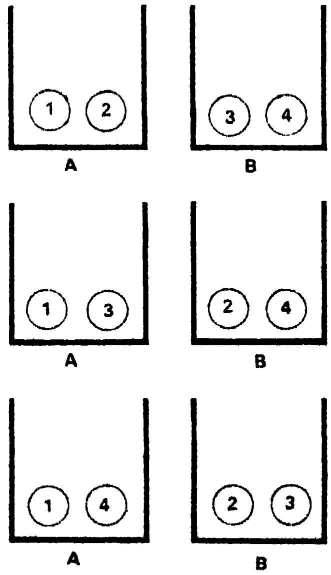


Fig. 2c



It is easy to see that the first specification gives us complete information about the system. However, two ' detailed states ' correspond to the second (Fig. 2b) and six to the third (Fig. 2c). Both contain some, but less than complete, information, and the third specification contains the least information. Thus, in general, there will be ' w ' detailed states corresponding to any specification, where ' w ' is some positive integer.

In entropy terms, the preceding paragraph can be summarised briefly. The three specifications correspond to entropies zero, k log 2, and k log 6, respectively. The entropy of a specification is thus defined as the logarithm of the number of detailed states corresponding to that specification, multiplied by a constant k (whose significance we do not go into here):

$S = k \log w$, where $S =$ entropy, and $w =$ number of detailed states . . . .(1)

Thus, minimum information corresponds to maximum entropy. When we have exactly specified a system, it is in exactly one ' detailed state ' and its entropy is zero.

From such simple origins a subtle and far-reaching theory has been built with ramifications in just about every field of science, from automobile engine design through mathematics to neuropsychology.

Any measurement on a physical system, usually gives us some, but less than complete, information. For example, let us take air in a room as our system and let us measure its volume, pressure and temperature. This tells us something about the numerous air molecules — for example their average energy. But we are far from having specified the position and velocity of each molecule which alone would constitute a complete specification of the system. Thus, our specification has non-zero entropy, which we could quantify by equation (1) if we could define and evaluate ' w ' in this case. Indeed this can be done, but we need not go into these technical details here. In any macroscopic process, say a chemical reaction like the burning of hydrogen in oxygen, we have only partial information about the reactants — we certainly do not know the exact position and velocity of every atom, molecule and photon participating in the reaction. We can speak of the entropies of the initial inputs and that of the final products and compare the two quantities.

Now that we have defined a uantitative measure of 'lack of nformation', we can also obtain a easure of 'information' in the llowing manner; suppose we change e specification of a system so that s entropy decreases from an initial alue S_{initial} to a value S_{final}. We efine the information gained in is process as:

$$\Delta I = S_{\text{initial}} - S_{\text{final}} = -\Delta S \ldots (2)$$

The amount of information gained thus defined as being equal to the mount of entropy (lack of information) lost in the process. A positive ain of information corresponds to a egative change in entropy. 'Information', thus, is also termed 'negenropy'.

The laws governing the changes of ntropy in physical processes are very imple:

A. The entropy of an isolated closed) system can never decrease second law of thermodynamics). n any process through which an solated system passes, the entropy of he final products is larger than that f its initial inputs.

B. An isolated system tends to a tate of equilibrium at which its ntropy is a maximum for the given onditions (volume, energy, etc). It ollows from this law that a system hich is not in equilibrium has less han maximum entropy, and, conersely, a system which has less than aximum entropy is not in equilirium. Such systems are known as non-equilibrium' systems.

What about 'open' systems — ystems that can exchange matter nd energy with their surroundings? uch systems *can* undergo a decrease f entropy — but only if the suroundings undergo an increase of ntropy so that the second law of hermodynamics applies to the larer, closed "system-plus-surroundngs" system.

Now let us go back o examine the dictum that "any rocess of organisation requires the ntervention of a conscious, intelligent gent". In any process of organisaion, a number of components are rought into a definite and welllefined relation with respect to each ther. Crudely speaking, we may ay that each component of an organised system sits in a 'container' ormed by the remainder of the sysem. This process can be seen to e qualitatively akin to the "ballontainer" specification example, but vith many containers and perhaps nany different kinds of balls. ***Thus, n organisation process is intimately conected with a 'decrease in entropy' or an increase in information'***. It follows that a *closed* system cannot spontaneously increase its organisation.

The human body, in fact, any biological creature, is a highly organised system. From the moment that the fertilised ovum begins to divide and multiply, and throughout childhood growth, till the time of attainment of maturity and adulthood, the degree of organisation increases progressively. On the other hand, during the process of living, during metabolism, there occur wear and tear — tissues break down, entropy increases . . . yet these tissues are replaced, and a reconstructive process also takes place which reduces the entropy and re-establishes the organisation of the system. What is 'responsible' for the increase in organisation, for the reduction in entropy, in the processes of growth and reconstruction? Do the above constructive and reconstructive processes in the human body, and other living creatures, violate the second law of thermodynamics? Is it necessary for some intelligent agent to intervene, for a miracle to occur, in order that life may exist and reproduce?

Since miracles and superstitions often conceal themselves in pockets of ignorance, it would seem to be an important cultural task to turn out these pockets, wherever possible, and to try to identify the source of biological order.

The first point we must take note of is that a biological system, say, the human body, is not an isolated system, but is very much an *interacting open system*. It receives sensory stimuli, eats food, drinks water, breathes air, exhales carbon dioxide, excretes feces, urine, etc. Food, at a more structural level, consists of complex molecules like carbohydrates (for example, glucose), proteins, lipids, etc. Thus, the human body regularly ingests complex molecules of the categories mentioned above.

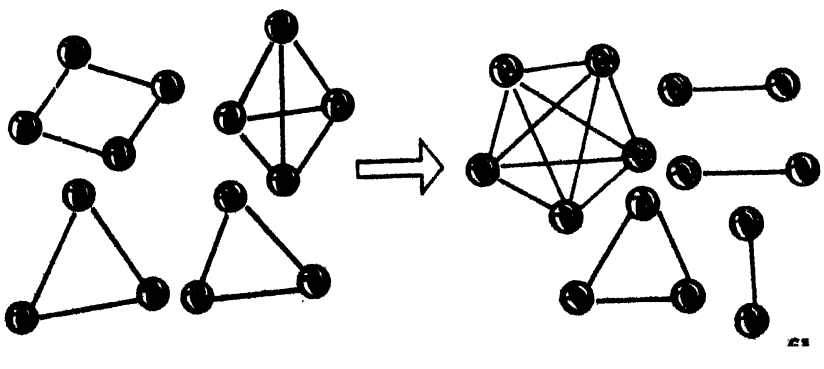
Now the biological life processes consist of two basic types — catabolism and anabolism. In the first, the complex molecules like glucose, amino-acids and fatty acids are 'burnt' in oxygen and broken down into simpler molecules like CO_2, water, nitrogenous wastes, which are then excreted in various ways. The entropy of the by-product molecules is much larger than the entropy of the initial molecules. In information terms, there is an outflow of 'information' during the process of catabolism, which supplies the anabolic processes which are characterised by an increase in order. Thus, rephrasing, we may say that biological organisations undergo two kinds of processes — one in which entropy increases (catabolism), another in which entropy decreases (anabolism). The various *biosynthetic* processes like formation of polysaccharides, proteins, DNA, RNA, and the 'higher' organisation processes mentioned earlier like reproduction of cells, are examples of the latter.

In a certain sense, even the process of thinking might be considered as a "higher" anabolic process. "Understanding" or, "coming up with an idea", consists of organising a set of disparate facts or data elements into a more coherent structure. Does entropy play a role here, too? Since neurophysiological, *material* processes underlie all mental functioning, the organisation of disconnected ideas into coherent understanding must correspond to a material organisation process in the neural network of the brain matter. We can certainly speak of the entropies of this *neural material* before and after the achievement of 'understanding'. (To the best of my knowledge, however, we are far from being able to *measure* these entropies in any thinking human.)

Consciousness and intelligence are also biological organisation processes, and the corresponding reduction of entropy could not take place without a "flow of negentropy" from an external source. In this case the external source is most likely the various catabolic processes in the body. In retrospect, we need to *invert* our original dictum to obtain a correct formulation: it is not necessary that, underlying biological organisation, there should be an intelligent 'miraculous' agent; rather, "consciousness and intelligence require a process

(*Contd on page 63*)

Fig. 3



Why do waves break?

The breaking of waves on the seashore is a fascinating sight to watch. But, why do waves break? What happens during breaking itself? Even after a hundred years of theoretical and experimental study, there are large gaps in our knowledge about this very commonplace phenomenon. Some understanding, though, has been reached on the conditions just before and after breaking.

What makes a study of breaking waves so important? One could cite a variety of reasons. Such waves enhance the air-sea exchange of gases and particulate matter, transfer horizontal momentum to surface currents, provide a source of turbulent energy to raise the upper layers of the ocean and can, at times, cause largescale destruction to man-made structures. It is well-known that large areas of our seashores are being eroded by waves.

An ocean wave is characterised by its wavelength (distance from crest to crest), water depth and wave height (Fig. 1). The inertia of the fluid, the pressure gradient and the acceleration due to gravity, are the three dominant forces acting on ocean waves. When the depth is greater than half the wavelength, the wave is in deep water, since it does not feel the effects of the bottom portion. Smaller values correspond to shallow waves. The other important ratios besides (d/λ) are wave steepness (H/λ) and height-to-depth ratio (H/d). When these quantities are less than one, the wave can be treated mathematically as a small amplitude wave. The profile of such a wave is symmetric about the vertical line passing through its crest.

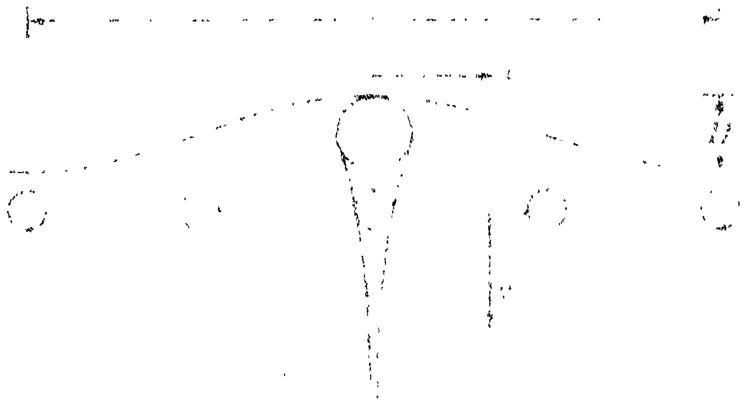


Fig. 1 In a small-amplitude sinusoidal wave in deep water, the fluid particles have circular orbits (indicated by arrowheads). The orbital radii decrease rapidly with depth

The approach so far has been to start with small amplitude waves and to consider progressively higher symmetric waves which propagate without change of shape in water of constant depth. For a fixed wavelength and depth, there exists a wave of maximum height which is just about to break. Analytically, one corrects the small amplitude approximation for the effects of increased wave height in successive order until sufficient accuracy is obtained. Each successive correction may be thought of as one member in an ordered series of corrections called a perturbation series. It is difficult to do algebraically higher-order corrections and, indeed, the tenth-order deep water correction was not obtained until 1914 and the fifth-order general depth one was found in 1955. Computers have, recently, enabled the series to be expanded to very high order and summed efficiently, thus providing accurate answers up to very near the highest wave.

The computations have shown that for low — but finite — amplitude waves, the speed of wave propagation (the phase speed) increases with the wave height. The wave profile no longer remains symmetric about its mean level, but instead the crests become higher and sharper and the troughs flatter. The phase speed, momentum and energy of the waves were found to increase with wave height, reach a maximum and then decrease as the highest wave was approached. An important observation was that the highest wave is not the most energetic as had always been assumed.

In general, at a wave crest the fluid particles move forward at a speed less than the phase speed and as higher waves are considered, the particle velocity approaches the phase speed. In the limiting case, the two velocities become equal. A further increase in wave height will cause the fluid particles to overtake the wave itself and breaking will ensue. In the reference frame moving with the wave, the water comes to rest at the crest and attains a sharp point with an inclined angle of 120° (Fig. 2). Roughly speaking, a wave will tend to break either when the wave height reaches about a seventh of the wavelength or when the water depth shoals to about 1·2 times the wave height.

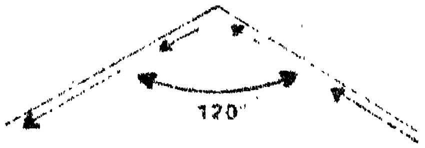
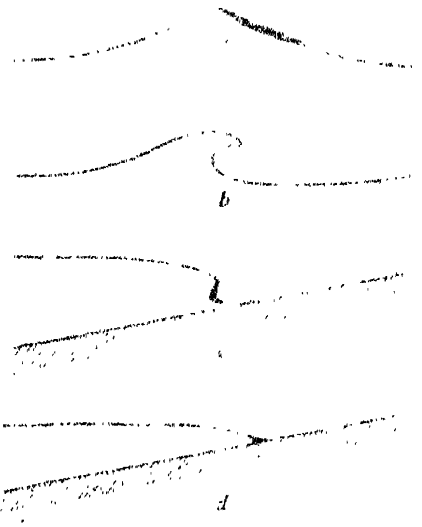


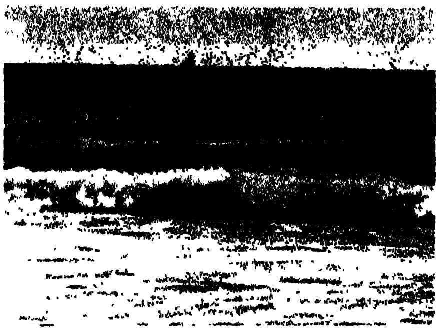
Fig. 2

Several laboratory experiments have been carried out to test the validity of the steady wave theories. Indeed, it is difficult to produce very high waves which remain steady and do not break in such experiments. Though some agreement between theory and experiment has been reached, there are more discrepancies, since small-scale controlled laboratory experiments cannot be correctly extrapolated to actual oceanic conditions.

Laboratory experiments with shoaling waves, however, indicate that breakers can be classified into four main types — spilling, plunging, collapsing and surging (Fig. 3). A spilling breaker occurs when a steep wave approaches a gradually shoaling beach and has a turbulent plume of frothy water running down its forward face.

Fig. 3 There are four main breaker types: (*a*) spilling, (*b*) plunging, (*c*) collapsing, and (*d*) surging





ig. 4 Above: Plunging wave in shallow vater. Right: (top) Collapsing breaker; and bottom) surging wave

In a plunging breaker the wave steepens and overturns, ejecting a jet of water from near its crest which eventually strikes the surface below. In a collapsing breaker, the wave overturns not at its crest, but lower down the forward face, and a region of white water forms possibly due to the close proximity of the bottom. The surging breaker moves up a steep beach as the forward tip of a low wave. It resembles a standing wave formed by total reflection from a vertical wall, but a small amount of turbulence may be present at the beach face. Spilling and plunging breakers can also occur in deep water. Collapsing and surging breakers do not occur in deep water.

Experiments with breaking waves in shallow water have concentrated on how the ratio of wave height to water depth at the break point (H_b/d_b) and the ratio of breaking wave height to initial wave height (H_b/H_∞) vary with the initial wave steepness, and beach slope. But not a great deal of confidence can be placed on some of the empirical relationships derived on the basis of some scattered experimental data. What is more, no analytical theories adequately describe the time-dependent process of wave breaking.

After a wave has broken, it advances shoreward as a bore. Recent numerical investigations have followed the water up the beach until its forward tip gets very thin and then to follow its subsequent rush seaward (backwash) which itself develops into a bore. The backwash stage may be of significance for sediment transport studies.

The above is a summary of an excellent review on " Breaking waves " by E. D. Cokelet of the Institute of Oceanographic Sciences, Wormley, Surrey, UK, and published in *Nature* (**267**, 769, 30 June 1977). Next time, you watch the fury of a breaking wave, remember that much remains to be understood of this most commonplace phenomenon.

K.A.N.

ENTROPY *(Contd. from p. 61)*

of biological organisation ". As for biological organisation itself, its needs are simple: it can survive on a diet of ' negentropy ' from an appropriate source.

Of course, the entropy of the final products of the anabolic and catabolic processes together must be greater than the entropy of the initial inputs — the second law of thermodynamics is not violated. We may summarise by saying that the living organism takes in highly organised food structures, converts a small part of these into even more highly organised tissue structures, together with the bulk of disorganised molecular by-products, which it discharges (shown schematically in Fig. 3, p. 61). The source of biological order in the higher organisms is, thus, primarily the food that it " eats ", or ingests.

Having lost his accommodation within the biological organism, our " intelligent agent " is compelled to climb into his only possible refuge — the food molecule. Granted that the source of biological order in humans and other higher organisms is the food molecule, but how did the food molecules acquire their higher organisation (their negentropy, if you wish)? We will examine this question in a subsequent discussion.

VIVEK MONTEIRO

IN LIGHTER MOMENTS

That cowpox provides immunity from smallpox was very well known to village dairymen. Jenner is generally credited with the discovery of the relationship between the two diseases by making the " vaccination " experiment in 1796. But, in reality, the first to perform such an experiment was another Englishman, a Dorset peasant named Benjamin Jesty. He had begun trying out this " immunising " in 1774 on the members of his own family, but he was ignored. And Jenner almost certainly would have missed recognition if he had failed to get support from abroad — the Royal Society was originally not prepared to accept his own evidence.

* * *

The German chemist, Julius Lothar Meyer was more fortunate than most scientists in the matter of priority. In 1882 the Royal Society awarded its Davy Medal to him jointly with the Russian chemist, Mendeleev, for contributing to the formulation and development of the Periodic Law of the elements. Generally regarded as the father of the Periodic Law, Mendeleev's first clear statement was published in 1869, followed by its final version in 1872, while Meyer had drawn up in 1868 (though not published) a classification of elements similar to Mendeleev's 1872 version. Even in 1861 Meyer had published tables of the elements in order of atomic weight in his book *Die Modernam Theorien der Chemie.*

* * *

At the historical 1860 annual meeting of the British Association which witnessed the great debate between William Wilberforce and T. H. Huxley over Darwin's *Origin of Species*, when order was restored and the chief actors had retired to their seats, suddenly an old man stood up with a copy of the Bible in his hand and shouted at the top of his voice: " I believe in its unimpeachable authority and deny the claim of the *Origin* that it was a logical statement of fact. . . . How much I regret its publication. . ." He was none else than Admiral Robert FitzRoy, once the captain of *HMS Beagle*, on which the ' creator ' of the *Origin* had made his epoch-making voyage.

* * *

The second conference of chemists of Europe held in 1860 broke up like that of 1840 (both were organised by Gerhardt and Laurent) and failed to reach any agreement on any problem. The only commonly shared result of the conference was that each member dispersed with a copy of Cannizzaro's little-known pamphlet, *Sketch of a Course of Chemical Philosophy.* The pamphlet made the most lasting impression on the German chemist Lothar Meyer, who said: " The scales fell from my eyes, doubts vanished and were replaced by a feeling of the most peaceful assurance."

S. N. MUNSHI

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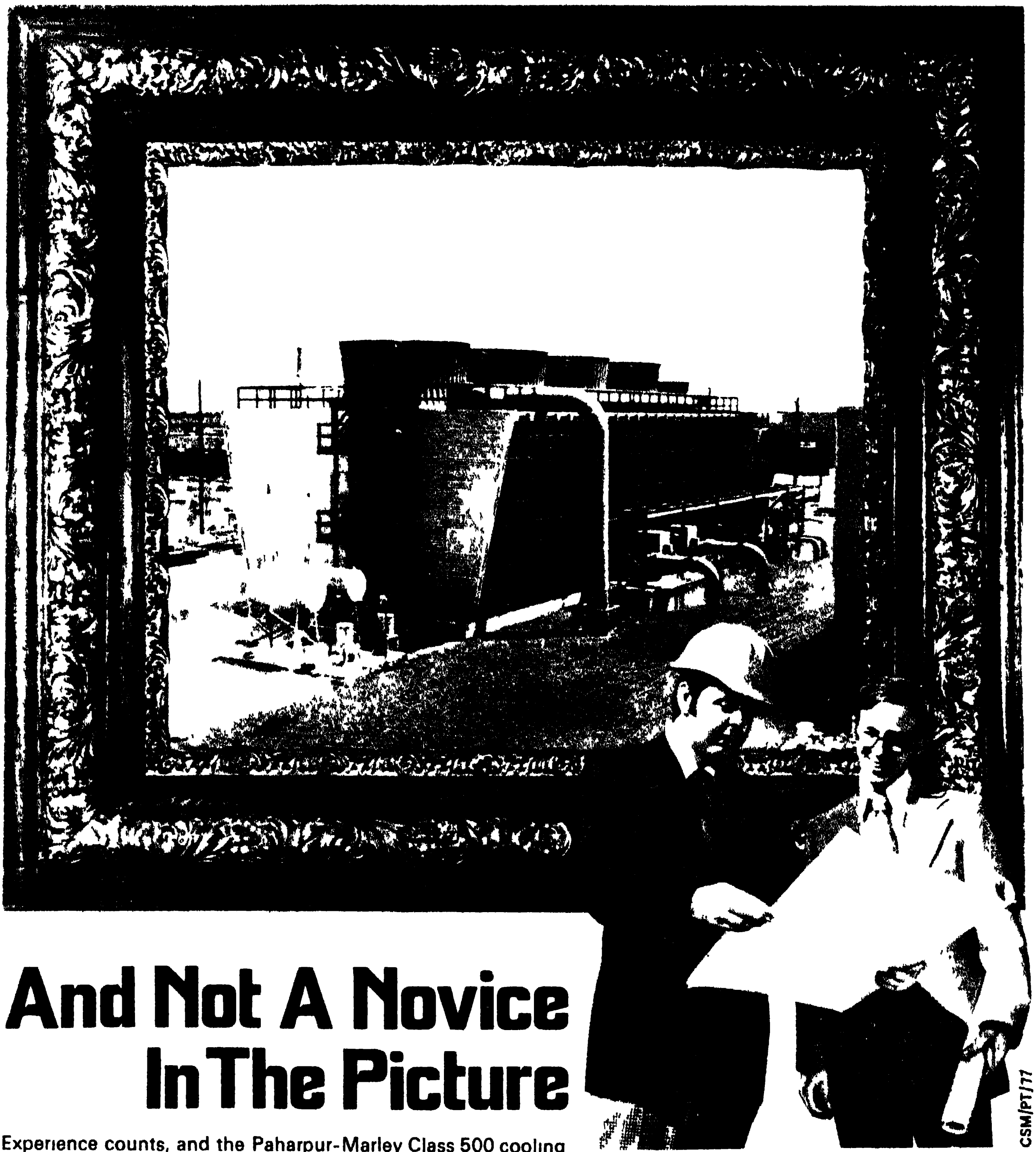

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RINTED CIRCUIT OARDS

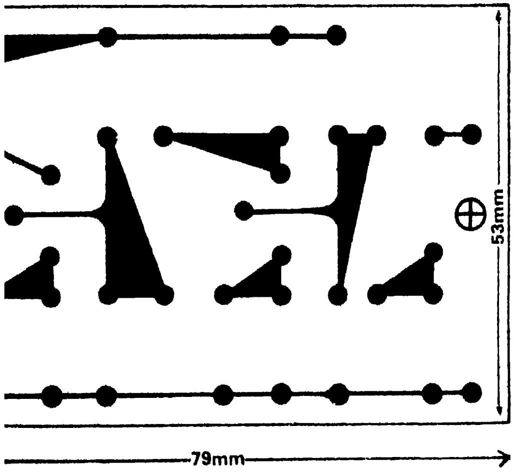
Printed circuit boards (PCBs) provide neater, lighter and compact circuit assemblies. By using these ards, the chances of making wiring ors are considerably reduced. At the ne time, they enable the circuit to be structed and assembled much faster. ey also provide excellent physical bility of the components as well as ir interconnections.

These printed circuit boards are conucted from copper clad laminates. Inating materials, for example, paper enolic or epoxy are laminated, either one or both sides, with copper foil of ckness from 0·025 mm to 0·25 mm. the two basic insulating materials, ligenously manufactured paper phelic is cheaper and more freely available. r almost all normal uses the singleed paper phenolic laminate is used.

On the single-sided printed circuit ards, the uncladded side, that is, where st of the components are mounted, is led the component side and the other e which makes the interconnections of circuit is called the printed circuit e. The chemical process given below is providing the required printed circuit ttern on this side by chemically etching unwanted portions of the copper clad.

Normally, external controls like itches, potentiometers, lamps, sockets, etc, of an electronic equipment are not mounted on the PCB, because of their placements. The transformers and power relays are kept aside because of their weight. The semiconductors which carry considerable current and thus become hot are normally placed on heat-sinks and not on the PCB.

Construction: Take a graph paper and all the components which are to be mounted on the PCB. Arrange the printed circuit (PC) pattern, by placing the components on the graph paper, as if the pattern were on the component side. Have a separate connection for mounting the components as well as for external leads. Never have two leads in one connection. For each connection, have a dot of at least about 3 mm diameter to avoid the breakage of the foil while drilling the laminate. Keep two interconnections of the pattern at least 2 mm apart. You will have to reduce these limits while designing the PC pattern for integrated circuits (ICs). Try to keep the flow of the circuit on the PC pattern, that is, keep input and output on two opposite sides, the D.C. supply on top and ground at bottom. Try to lay out the pattern in such a way that the interconnections don't cross each other. Arrange the interconnections between the connecting points of components. If unavoidable, you will have to have a 'jumper' wire on the component side. Use the minimum of these jumper wires and make sure that they bridge no component but only the PC pattern.

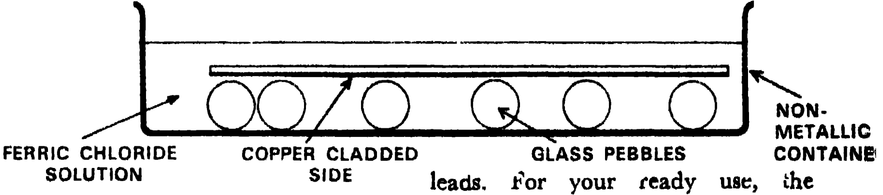


PRINTED CIRCUIT SIDE VIEW

The following procedure is for transferring the pattern drawn on the graph paper to the copper foil. This procedure is suitable for constructing experimental PCBs, where just one or two are required.

When the pattern is complete on the graph paper, take a tracing paper and trace the PC pattern on it. Cut a laminated board of the required size and wash it thoroughly with soap and water to remove the oil stains and finger-prints. Now, take a fresh carbon paper and keep the carbon side facing the copper side of the laminated board. Keep the tracing paper on the carbon paper in the reversed way. Thus, the component side view of the pattern will become the required PC side view. Now trace upon the tracing paper, from its reversed side. with a hard pencil so that the copper clad will get the required PC pattern from the carbon. Remove the carbon and tracing paper and paint the pattern with India ink or any air-drying enamel paint. Let it dry out for about 24 hours.

Make the etching solution in a tray or dish-like non-metallic container, for example, glass or plastic, of one part ferric chloride in powder form with two parts of water. Stir the solution till the ferric chloride gets completely dissolved. The quantity of the ferric chloride solution required is just enough to immerse the painted laminate. As the ferric chloride dissolves, the solution will become warm due to exothermic reaction. Put a few glass pebbles in the container to keep the board off the container's bottom. Maintain the temperature of the solution at 55 to 60°C by external means. Stir the solution gently, so that the solution will etch out the unwanted copper not covered by paint. The etching process will require 30 to 40 minutes. The etching strength of the solution gets reduced after processing a few boards. When the etching time get doubled, you will have to replace the solution. When the etching is complete, take out the board and wash it thoroughly with clean water and soap. Now, to uncover the painted PC pattern, clean the paint with thinner and soft/medium steel wool. Once again, wash the board with water and let it dry. Drill 1 mm holes, wherever required, to mount the components and to take out the external leads. For your ready use, the complete component side view and PC side pattern of the portable radio published in SCIENCE TODAY, September 1977, is given below. You can use the pattern in the same way, transferring the pattern from the reversed tracing paper.

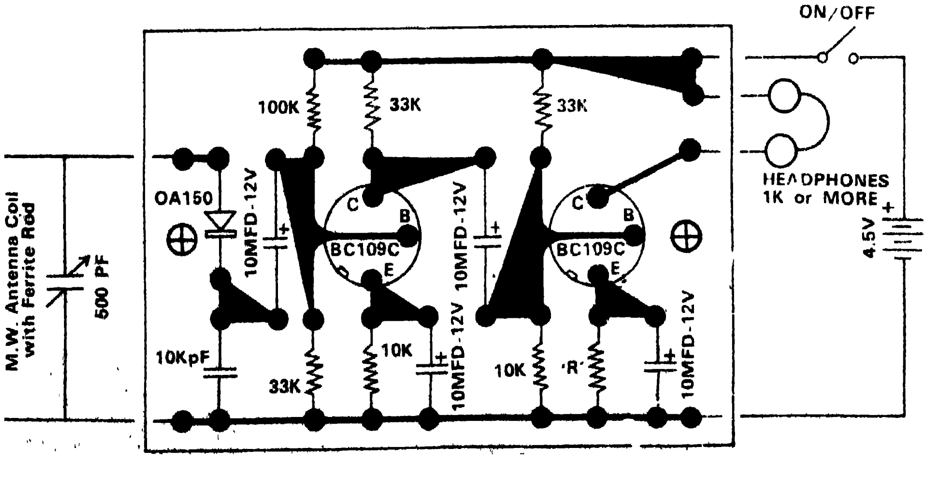


Warning: Though the ferric chloride etching solution is quite safe to handle, avoid direct contact with it. If you happen to get some on your body, wash the area of contact with clean water. Protect your eyes from the solution.

You will need:

Ferric chloride: 450 gm (cost: about Rs. 5 per kg); glass pebbles, 15 nos.; non-metallic container; copper clad laminate, etc.

ANIL V. BORKAR



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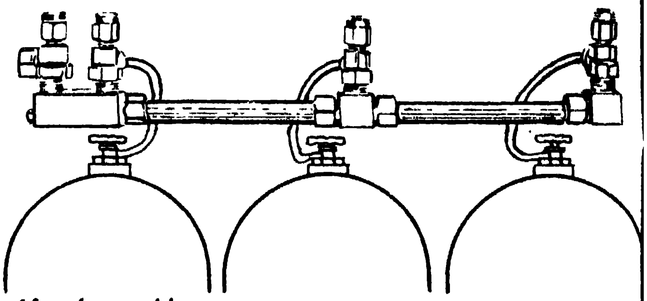

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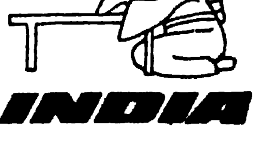

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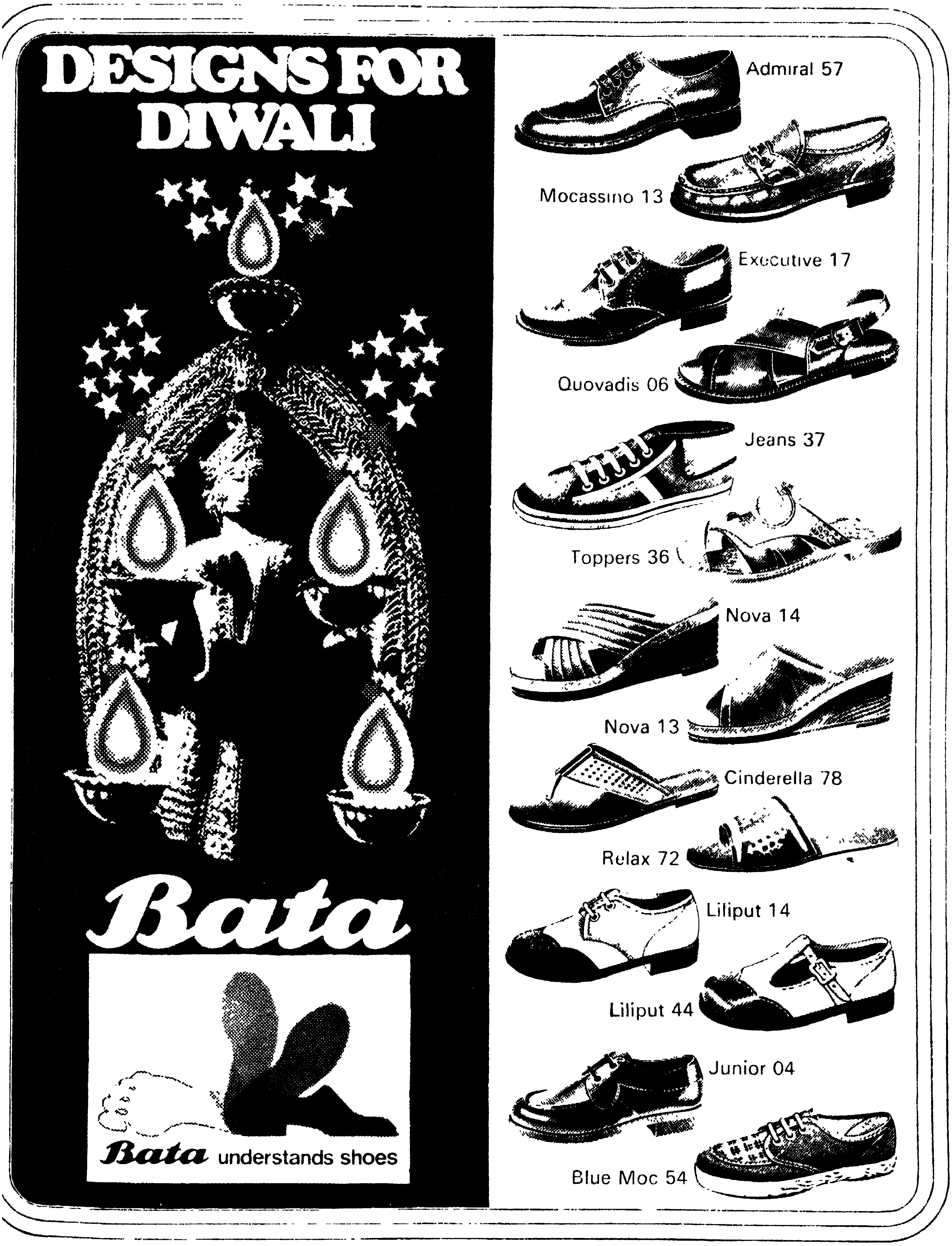
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